EDUCATION FOR INDUSTRY AND CITIZENSHIP

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PREFACE

AT present the educational system stands at the cross-roads. Two possible paths are available for future developments, but these lead in very divergent directions. Thus it is essential that citizens should critically examine the reputed benefits and disadvantages which are associated with each line of development.

If one of these paths is followed education will gradually be organized on a highly specialized basis which will conform generally with the specialized organization of industry. Consequently it is claimed that a development along these lines would be of great value to the nation, giving rise to increased efficiency in industry. Whether this is so or not is still a matter of opinion, but it is certain that the adoption of such a policy would result in the general cultural aims of education being gradually superseded in the effort to provide added facilities for detailed instruction in specialized activities.

To the author such a prospect appears most undesirable, and so in the following chapters an effort is made to set out the basic ideas of the alternative mode of advance. Here the primary effort of the educational system would be directed towards amplifying the general cultural background of citizens, so that this common heritage would be available to counteract the disintegrating tendencies associated with the specialized organization of industry. Admittedly citizens of the future will require specialized technical training; but it is to be hoped that this will always be regarded as something that is merely supplementary to their general education, and that it will never occupy the position of primary importance in the educational organization of any land.

In conclusion the author wishes to express his indebtedness to the organizations and individuals who have played so important a part in the preparation of this report. In this connection especial acknowledgment must be made of the contribution of the Carnegie Corporation of New York, for this body provided the financial assistance which enabled the author to collect the facts on which this report is based. In addition the author wishes to express his great indebtedness to the Society for the Promotion of Engineering Education for the inspiration and information obtained from its various publications, and to his wife for the encouragement and assistance which enabled this report to be brought to completion.

The University of Melbourne,
May, 1936.

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PART I

GENERAL EDUCATION

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CHAPTER I

THE OBJECT OF EDUCATION

IN any consideration of educational policy and organization it must be remembered that the primary objective of this branch of human endeavour should be to so develop the latent talents of individuals that they will be able to function fully in the task of increasing the physical, intellectual and moral well-being of the world. But a survey of existing educational schemes shows that in many cases this basic objective has been largely overshadowed by a growing demand for the introduction of highly specialized forms of education, which have as their aim the training of men for some relatively narrow and sectional interest.

Thus communities now insist that youths should be trained as doctors, lawyers, engineers, or ministers rather than as members of a community of people bound together by common interests and by aspirations for the improvement of humanity. Indeed, in certain fields it would appear that the training is directed towards nothing more advanced than filling the student's mind with factual knowledge that is directly applicable to the chosen field of industrial work; while little or no effort is made to develop those critical intellectual powers which would enable the man to do really constructive work in the community. In short, there is now a growing tendency to regard education as a means of training memory and skill rather than of developing the intellect.

Admittedly the immediate effect of the general adoption of this outlook would be the production of groups of expert specialist workers; and so long as that group of trained thinkers, which would be responsible under such a scheme for the initiation of new policy and the correlation of general developmental activities, maintained its efficiency, vision and enthusiasm, this system should give reasonably satisfactory results so far as the mere production of goods is concerned. But if this central group should lose its driving power the whole system would quickly stagnate or retrogress. It is, therefore, most unlikely that the adoption of this 'specialist' outlook towards education would result in the maintenance of a vigorous community over any lengthy period.

Further, such a scheme could be successful only while the general body of workers in the community remained content to be treated as glorified automatic machines, thinking of nothing outside their narrowly defined tasks. But average men soon tire of such a condition, and their final reactions against a system that relegated

them to such menial service would be both violent and far-reaching in its effects.

Consequently it is essential that all sections of the community should be actively interested in the objectives of the educational system. At the present time the importance of such interest is continually increasing. In earlier days, when education was still really a personal affair, its objectives were not matters of such pressing importance, for then education directly affected the interests of only a small proportion of the community. But with the growth of the modern State the field of influence has been vastly extended, since practically every State now aims at establishing an educational system which will influence the outlook of all citizens. Therefore it is essential that the public in general should show sufficient interest in these problems to ensure that the educational facilities will be utilized for the benefit of humanity as a whole, and not for any selfish or sectional ends. If this objective is to be achieved it will be necessary to replace the essentially nationalistic outlooks, which up to the present have pervaded most schemes of mass education, by a broader international one.

This new outlook would place its major emphasis on the appreciation of the viewpoints and cultures of other nations, and on the necessity for international co-operation in the development of the world's resources, rather than on utilizing education as a weapon of international competition. In this connection it is interesting to remember that, although a man, whose education has consisted chiefly of specialized instruction in some trade or profession, will be reasonably equipped to compete with a similarly educated man of any other nationality, he will normally find it difficult to appreciate the other's viewpoints on questions of international importance. Actually the lack of understanding which results from specialized education is not confined to the international realm. Frequently it causes lack of co-operation between the various classes of society in a single State.

So it is to be hoped that the vital importance of general education will be realized by the framers of future educational systems. No scheme of instruction can achieve lasting good unless based upon a broad foundation of general studies, and unless the later years of specialized work are supplemented by a continued interest in cultural activities.

The realization of this is of especial importance at the present time, since the continuing progress of science will soon place in the hands of the State an ability so to harness the resources of Nature that poverty could be abolished. This opportunity will only be utilized if the public has by then been educated on such broadly

cultural lines that it will regard co-operation as having a greater virtue than competition.

Thus the basic objectives of an educational programme should be to advance the public's understanding of social groups and national communities other than their own, and to establish paths of communication and co-operation between these various groups. So it should train minds for logical thought, it should encourage constructive effort, it should foster a spirit of research, and it should teach men to think of life as a whole rather than to concentrate their outlook entirely on some specialized job on which they happen to be engaged during working hours. But, above all else, education should teach men to examine new concepts without fear or prejudice, for if there is to be progress the schools must act as creators of new standards—not as the slaves of existing ones.

CHAPTER II

EDUCATION—A TRI-PARTY AFFAIR

DURING the Middle Ages education began to play an increasingly important part in the lives of the nations of Western Europe; but at this period it was primarily an individual affair. The searcher after truth and knowledge pursued his studies because he wished to learn for his own satisfaction and for the improvement of his own mind, rather than with the object of applying his increased knowledge to the solution of some pressing human or industrial need, or of improving his personal financial position.

Consequently education remained primarily a personal affair in which students studied their chosen subjects in the ways best suited to their individual needs; and for a considerable period organized society paid but little attention to the students, and made little or no effort to control or direct the nature, extent, or method of their studies. Probably the first examples of a partially directed type of education are furnished by the various religious bodies, which were for centuries the chief centres of learning, for here a certain general directive oversight of the studies of the initiates may have been maintained by the more advanced members of the orders.

But it is indeed a far cry from these conditions to those of the present time, when the great bulk of education is conducted on strictly regulated lines under the control of central authorities, and where practically all students study for some very definite and immediate objective.

Admittedly a number of people do still study in their own ways along lines that they have determined for themselves; but these students differ substantially from the independent workers of early years, for a critical study of their objectives reveals that though their studies are certainly of an individual nature the work is often no longer a truly disinterested search for truth. Indeed in most cases the individual aims at applying the knowledge so obtained to the direct improvement of his personal prospects.

In addition to these changes in objective and mode of control the modern educational position differs from that of earlier years because of the vastly increased proportion of the community that is now affected by educational policy and procedure.

Indeed the present aim of most States is to ensure that all citizens spend a certain number of years in at least passing through a prescribed educational programme, for it is generally realized that some such training is necessary if citizens are to take an

intelligent and helpful part in developing the resources of the community. Thus, as the interests of the State have been gradually added to those of the individual, the objectives of the educational process have been modified to suit these dual requirements.

During recent decades the position has been further complicated through the rise of a third controlling influence in the educational world. In this period employers as a class have begun to realize the importance of education as a factor in an orderly industrial system.

Actually this development is of great importance since employers normally look upon education from a more utilitarian viewpoint than does either the State or the individual student. Indeed their primary interest in education is frequently that of moulding the system so that it will give a steady supply of trainees who are adequately skilled in the appropriate industrial or professional knowledge. In many cases they are quite unconcerned as to the extent or quality of the general education of these recruits.

Thus education can no longer be regarded as a disinterested, individual pursuit of truth in which the desires of the student reign supreme. Instead it must be recognized as a tri-party problem. Admittedly the desires of the individual student should still play an important part in fixing the details of the educational scheme; but these must now be conditioned by the requirements of the State and the employer, for these latter parties have very definite interests which must be conserved.

Unfortunately the educational interests of these three parties are frequently antagonistic, or even irreconcilable, and the maintenance of an even balance between them is undoubtedly the greatest educational problem now requiring solution. All three parties have very definite rights, and the ultimate well-being of any community depends largely on its educational system attaching the correct importance to the claims and requirements of each party.

Thus it must be recognized that each individual student has a right to receive such instruction as will enable him to fully develop his latent capabilities for thought and work, and to select the type of instruction most suited to his needs. But in achieving these ends each student must keep in mind his responsibilites as a member of the State, for unless his training fits him to assume the social and political responsibilities inherent in a communal type of life the State itself will quickly fall into chaos.

Then on the other hand the State has a right to insist that citizens should develop their latent capabilities to the full so that these will be available for the service of the community as a whole. Otherwise it is probable that the State will not maintain its place

in the world community. Further, the State has a right to assist its citizens to enter those callings which are most vital to the life of the community, and to organize education in such a way that students will be trained to take an intelligent part in social and political life. But these rights are accompanied by such responsibilities as respecting the individuality of students, ensuring adequate endowment and finance for the educational scheme, maintaining a balance between conflicting interests so that one section does not profit at the expense of any other, and ensuring that the benefits of the system are freely available to all members of the community who are capable of benefiting therefrom.

Again, employers can reasonably expect that the educational system will provide them with a steady and adequate supply of recruits who have been suitably trained in the theory and practice of the various trades and professions. Without this assurance no industry can flourish. At the same time employers must realize that the educational system is not merely a training ground in specialized technical proficiency, and so must be prepared to organize their recruiting and training plans to fit in with the general scheme of instruction.

Thus there is a certain amount of overlap between the interests and responsibilities of the several parties, and in order to avoid any undue conflict it is essential that each party should adopt a reasonably tolerant and liberal view of its rights and duties. However, in their endeavours to increase the production efficiency of industry many employers, and certain educationalists, have recently demanded that the primary objective of an educational scheme should be the provision of specialized technical training for future workers. This demand can be met only by decreasing the emphasis that the system places on training for the general activities of citizenship, and represents an unwarranted intrusion upon the rights of the individual.

At the present time these rights are also being encroached upon by the activities of certain States. This fact is most disturbing since the State is the body which should normally be engaged in maintaining an equitable balance between the interests of the three parties. Therefore, although this danger is not so pressing in English-speaking lands as it is in certain others, it is desirable that a review of the question of State control of education should be included in this work.

During the earlier parts of the 19th century the British State took no interest in any form of education, as this was left entirely to voluntary agencies; but in 1870 an Act was passed which made primary education compulsory, and provided for the establishment of a system of Board Schools financed and controlled by the local

rating authorities. This innovation was due chiefly to a growing realization that all individuals were entitled to a certain amount of education; and since the burden of providing this mass education was too heavy for any voluntary agency, a system of State organized primary schools was developed parallel with the existing private schools.

At the time of its introduction this step was severely criticized by many leading citizens who believed that the entry of the State into the field of education would cause a diminution of personal liberty. It was for this reason that the educational activities of the State were originally confined to the instruction of children of poor parents. The opponents of the scheme advanced the experiences of Prussia and of China as examples of the ill effects of a government controlled system of education, and in this connection Disraeli is quoted as having said that 'The best way to ensure implicit obedience is to commence tyranny in the nursery.' But the necessity for some form of universal education was so urgent that these objections were over-ruled, and by the end of the century primary education had been well organized as a State activity.

In 1902 secondary education was included in the scheme of publicly supported education, and local authorities were created to organize all instruction below the University standard. These authorities were responsible for conducting the educational system within their own borders, while the State set up a system of official inspection, and provided government grants to local authorities whose schools were favourably reported upon by the inspectors.

While these changes were occurring in connection with general education a similar development was being carried through in the technical realm, where training had been initiated through private enterprise as early as 1825. State assistance in this branch of education began towards the middle of the century, taking the form of annual grants to the various Schools of Design that had been set up by the Board of Trade from 1837 onwards. After the Exhibition of 1851 the State also gave financial assistance towards the teaching of science in similar schools.

During the latter part of the century the increasing pressure from foreign industries brought the problems of technical education to the fore, and the State finally placed this work under the control of local authorities, which were given power to finance their activities by levying rates. In 1902 technical and general education were placed under the control of a newly appointed set of Local Educational Authorities, which received support from State grants, and were generally controlled through the activities of the Board of Education.

Thus by this date all forms of education below University standard were the direct concern of the State, and were largely subject to its control. But although the British State has thus accepted the responsibility for primary and secondary education it has not endeavoured to achieve a monopoly of instruction in these educational spheres, and at all times a substantial section of the community has received its education through non-governmental schools. Probably with the continued growth of State-assisted secondary education this proportion will be a gradually diminishing one; but up to the present private school students have played a very important part in the general life of the nation.

In addition to its activities in primary and secondary education the State has recently accepted a considerable degree of responsibility for University education, and now makes large annual grants towards the costs of these institutions. Up to the present, however, it has been content to subsidize these without endeavouring to control their organization, standards, or methods of instruction.

Thus the British State is now actively interested in all levels of education, and in the sub-University levels it is able to enforce its educational viewpoint on the majority of the community. Therefore the nature of this outlook is of ever-increasing importance to all citizens. Fortunately history shows that English-speaking states have been fairly liberal in their attitude towards education; but the recent rise of the authoritarian State in various lands makes it desirable that British citizens should jealously guard the freedom of their educational systems. The control of education is undoubtedly the real key to the prolonged maintenance of any form of dictatorship. To achieve this end the educational system must be so modified that it will produce minds that automatically obey instructions and tend to rely on established precedent, rather than minds that are continually endeavouring to arrive at logical conclusions on the basis of their own reasoning.

The tendency for this authoritarian outlook to be incorporated into the official policy of the State is undoubtedly the greatest danger associated with the State control of education. It must be remembered, however, that this danger would not be entirely averted merely by removing education from the sphere of the present activities of the State, for one of the first actions of any dictatorship or fascist regime would be to make the State's control supreme and universal in the educational realm.

In contra-distinction to this possible danger State control affords certain very definite advantages. For example the establishment of uniform standards of tuition over wide areas benefits the students who change their place of residence, while certificates of compe-

tence issued by such an authority are generally recognized by employers. Also the existence of a central control facilitates the adoption of schemes of vocational guidance whereby the danger of temporary gluts and shortages of recruits for particular life occupations can be reduced. But more important than anything else is the fact that State control is the only adequate method of securing the financial support that is essential for the success of any scheme of mass education, for if any scheme of universal training is to be really successful it must not impose any considerable direct charges on either the students or their families.

But these advantages are not obtained automatically. The success of any scheme depends finally upon the public insisting that it be a success. Otherwise its control will gradually pass from men who regard the advancement of the scheme as their life-work to ones who will use the system merely as a means of livelihood. Once this occurs State responsibility becomes a menace, while State control then spells the doom of all true education—all true progress ceases; tradition rather than enterprise becomes the guiding principle of the administration; and the educational system is quickly utilized by some selfish section of the community to advance its own ends.

As an example of the danger of State control reference need only be made to the history of technical education in France, where the whole system stagnated for some forty years as a result of the controlling government departments losing their educational vision about the year 1860. Before this occurred France had led the world in technical education, but this unfortunate lapse altered the whole position and allowed other lands to entrench themselves firmly in the export fields.

In view of these facts it is to be hoped that, while the State will accept an ever-increasing responsibility for financing the education of its citizens, it will not condition this support by demanding any increased control either over teaching methods or over the content and nature of the instruction.

CHAPTER III

THE ADVANCE OF EDUCATION

A CONSIDERABLE number of factors affect the advance of an educational scheme; but of these public opinion is the most potent, for in the last analysis an insistent public will secure that type of education which it really desires. On the other hand a quiescent public opinion will result in the educational scheme being quickly shaped to serve the needs of some sectional interest in the community. Admittedly a progressive government or an energetic head of a State system of education may develop the system in advance of public opinion; but these advances cannot be permanent unless the executive action is quickly backed up by an adequate body of public opinion.

Therefore it is necessary for the public to study the problems of education so that they can form their own conclusions as to the desirable lines of development. There are, however, certain factors that influence the formation of public opinion on educational questions. For example, it is controlled very largely by the tradition of the community, and this varies widely. In communities where citizens regard education as a luxury which should be enjoyed only by the privileged group, educational advances are usually fairly slow. In other groups education is regarded as an essential birthright of every citizen, and in these cases traditional enthusiasm often enables communities to triumph over severe economic disabilities which would otherwise prevent any material development of educational facilities.

But quite apart from the influence of tradition public opinion is influenced largely by the personal experiences of present-day citizens. If these have learned either in their own lives or through contact with other individuals that education is a distinct aid in work and in recreation they will support any public campaign for improved educational facilities. But if education has not been a vital factor in their own lives, if it has not taught them both to work and to play, or if it is now merely a dimly remembered discipline of school days, it is unlikely that these citizens will enter with enthusiasm into any campaign for better education. To them it represents so much wasted time, and they fail to see why they should be called upon to support such a system.

Then looking a little deeper the investigator finds an additional factor that tends to build up a favourable public opinion, for in most minds there is at least a latent desire to strive for a greater knowledge of, and control over, the affairs of life and of nature. Consequently there is always some body of thought endeavouring

to spread education over a wider and more profound field, and this acts as a leaven to the general community.

And finally public opinion is influenced to an ever increasing extent by the progress of education in other lands. This in itself is a major change in human outlook, for in bygone days nations were but little interested in the educational schemes of their neighbours. Now this indifference has been replaced by an active interest which is based on two rather distinct factors.

On the one hand the interest of some people in this problem arises from a belief that education and knowledge are the basic factors which should be common to all mankind, and so they wish to facilitate the interchange of educational methods, techniques and experiences between national units. Then on the other hand there is a body of opinion which sees all advances in foreign education merely as a threat to the economic security of their own nation. Consequently their interest is much narrower than that of the other group, their activities are usually confined to the scientific and industrial aspects of education, and their object is to ensure that the industrial workers of their country receive adequate training in comparison with those of all other nations.

These are the chief factors influencing the growth of public opinion; but it must be realized that mere growth is insufficient. To achieve any considerable effect on the national standards of education this opinion must be adequately and frequently brought before the notice of the appropriate administrative authorities, and this cannot be done without some special effort. In many cases this necessary momentum is provided through the activities of some enthusiastic individual or voluntary society that refuses to rest until the wave of public opinion which has been slowly gathering breaks over the controlling authorities and brings their outlook into line with the new requirements.

In other cases the trigger action is provided by some national or world calamity which releases the pent-up opinion in favour of some major alteration in educational methods. For example the recent growth of an international outlook in secondary schools, as opposed to the purely nationalistic views of pre-war days, is undoubtedly attributable to the calamity of 1914-18. Or, to take a further illustration, it was the threatened loss of export markets that finally forced the British authorities to abandon their traditional policy of restricting technical education to the training of artisans, and induced them to extend this type of education to those men who would finally occupy the more responsible positions in industry. This step was most important, as it marked the start of a really adequate system of industrial education for that country.

A further factor that sometimes stimulates educational affairs is the sudden emergence of some new invention which necessitates a major reorganization of the life of the community. The classic example of this was the application of steam power to industrial production. This led to a complete re-alignment of industrial relations, and finally necessitated the creation of a system of technical education to supplement the apprenticeship system which had previously given satisfactory service.

In opposition to these factors there are others that tend to retard the growth of a well-rounded educational system. Of these the most potent is the existence of a very high standard of material prosperity in the land concerned, for then the public becomes uncritical of existing institutions, and people forget that the prevailing standards of comfort cannot be maintained indefinitely unless their descendants are adequately educated. Consequently the nearer that a land approaches the luxury level of living the greater are the responsibilities that rest upon its intellectual leaders—the continued development of educational facilities should always be their chief concern.

A further factor which controls educational advances is the nature of the relations existing between the various social classes in the community, since the existence of sharply defined social classifications normally coincides with the maintenance of similar distinctions in the educational field. Thus in these communities it is usual to find that a general education is provided for the upper and possibly middle classes, while there is general agreement that a specialized industrial training is the best form of education for the working class. Such an attitude makes it practically impossible for the community to achieve any really lasting educational advance, since this is dependent on a general type of education being available to all members who are capable of profiting therefrom. However, under these conditions there may still be considerable advances in the specialized sections of the educational scheme. Indeed it is probable that these aspects will eventually be unduly developed relative to the general ones, for the greater voting power associated with the specialized instruction causes government departments to favour its development when allocating monetary grants.

This tendency for unbalanced development is further emphasized by the demands for specialized industrial education which are frequently made by parties whose sole interest in the question is that of improving the supply of labour for their particular industry. Within limits such actions are quite reasonable, but if carried to excess they eventually result in the educational system degenerating into an aggregation of specialized courses without the necessary core of general education.

At times the progress of technical education has been held up through the opposition of a section of the employers towards any further education of their employees. Fortunately such direct opposition is now rare; but in the past it has had a considerable influence on educational history, as employers feared that the development of education would not only interfere with their workshop arrangements, but that the trained men might become competitors of their original employers.

In view of these factors which tend to prevent the ideal growth of an educational system, it is most desirable that persons who are interested in the development of a progressive and balanced educational policy should work strenuously to establish a better informed public opinion on these questions. Otherwise the educational system will quickly cease to be a really vital factor in the life of the community.

Chapter IV

PRESENT EDUCATIONAL PROBLEMS

DURING the development of education in English lands certain important problems have had to be faced. The most vital of these was that of establishing a system of State-financed primary education, while the entry of the State into secondary and technical education represented further important advances. Other grave problems have arisen in connection with the establishment and maintenance of Universities, and some of these still remain unsolved at the present time.

Up to the present universal education has been treated as something rather apart from the general problems of life, but now the chief educational problem awaiting solution is that of definitely integrating education into that structure of social, industrial and moral relations which goes to make up the life of a modern community.

This problem is a many-sided one, but two of its aspects are of outstanding urgency and importance. In the first place it is becoming increasingly evident that the modern industrial system tends to progress in alternate booms and depressions. Possibly economists will finally evolve procedures that will lessen the severity of these phenomena; but for the benefit of those living in the intervening period it is necessary that society should immediately develop its educational system along lines that will alleviate the problems of total and partial unemployment. The second outstanding aspect of this question is that if an educational system is to be really successful it must train the rank-and-file of the community for leisure as well as for work.

These two problems challenge educational authorities in practically all industrial lands. We must discuss them in turn.

The School and Unemployment.—The unemployed of a community can be divided into several classes. First there are men who lack work because of the seasonal nature of their employment; secondly, there are those whose plight is due to the occurrence of an industrial depression in their land. A third group lacks employment because the trades in which they were trained have ceased to exist; and fourthly there is unemployment which is due to the failure of the social conscience of the community to keep pace with the inventiveness of man, and so with his increased power of production. The second class subdivides into two groups

corresponding to men who have been previously employed, and to youths who cannot even begin to work, although they have completed the normal educational programme.

Unfortunately education cannot do much to improve the lot of the seasonal worker, for this class is usually filled by men who gravitate to it either from choice or because of their lack of ambition. The lot of the other classes can, however, be considerably improved by educational methods.

For example, unless his natural powers of adaptability and resourcefulness have been ruined by his previous industrial discipline it is possible to remedy the plight of the man whose trade has ceased to exist by training him in some more modern craft or calling. Provision for this type of training should, therefore, be included in any comprehensive scheme of technical education.

However, the need for this provision will be largely controlled by the extent to which the industries of the community have adopted strictly specialized methods of production, for, although these lead to economic production of goods, they carry with them two definite hazards. The first is that the greater the specialization achieved in industry the greater is the probability that some new invention will suddenly render obsolete quite a number of trades and trade processes. And secondly, since a maximum economy in labour costs is obtained in specialized industries by restricting each worker to a narrow range of activities, there is a strong probability that the work will be organized in such a way that the men will quickly lose their original adaptability.

Therefore it appears that the problem presented by this particular type of unemployment cannot be solved solely by the creation of training schemes for displaced workers, and its complete solution can only be expected when employers as a class begin to consider the welfare of the nation in addition to the dividends of their shareholders. Probably this will be a relatively slow process; but experience in similar problems indicates that the interest of employers is automatically increased once the problem is made to have a direct financial bearing on them. For this as well as for other reasons it seems advisable to transfer an appreciable percentage of the cost of unemployment relief from the worker to the employer, on the understanding that firms which maintain the natural adaptability and resourcefulness of their employees should be exempted at least partially from this levy.

The remaining causes of unemployment—namely, the occurrence of industrial depressions and the tardy development of an adequate social conscience—are so interwoven that it is proposed to treat them together. In this case there are two chief problems to be considered. The first is that of utilizing the educational

policy to reduce the amount of this type of unemployment in any given community; and the second is the problem of improving the lot of persons who are so unfortunate as to lose their employment through some dislocation of industrial relations.

In the future a fuller understanding of economic laws will do much to reduce the severity of these depressions; but their final elimination will be achieved only when the conscience of mankind has been so developed by education that social problems will be settled in men's minds on a basis of ethics rather than of self-interest. The achievement of this state should be the ultimate goal of all educational work, and the general structure of educational programmes should be continually influenced by this consideration. But in addition to this long-range plan for the abolition of unemployment certain immediate improvements could be made in the position.

Of these the chief is that of controlling the total volume of available labour forces by varying the permissable school-leaving age. In order to achieve its best results this method should be utilized only as part of a long-range, continuously developing plan of educational advance, in which the nation's ever-increasing power of production would be paralleled by a corresponding reduction in the duration of the normal working life of all citizens. This has been the general policy of certain nations for many years, and the effectiveness of this procedure is clearly illustrated by the steady increase which has occurred during the last century in the school-leaving age of an industrial land such as England.

At the present time there are however signs that a further step should be taken in this direction, for even under existing conditions a large number of children in industrial lands remain voluntarily at schools after reaching the legal leaving age. There is also at present a large body of unemployed in all industrial countries.

Naturally the cost of any further advance in the school-leaving age would be considerable; but the adoption of this step would have two very important results. Firstly, a corresponding number of adult workers who are now unemployed would be re-absorbed into active work with a corresponding reduction in the cost of relief schemes; and secondly, the youths who would be retained at school under the modified scheme would be saved from the devastating experience of years of unemployment at their most impressionable age. Consequently the whole cost of extra-educational facilities necessitated by an increase in the leaving age should not be debited against the education budget.

But in addition to providing a means for reducing the actual number of unemployed education should also be utilized to amelior-

ate the lot of those who are workless. At the moment this class includes men of all ages and experiences; but if the school-leaving age were suitably raised this group would be composed chiefly of men of relatively mature years, who would have had at least some business or industrial experience.

On this basis the best aid that the educational system could give to this class of men would be by providing relatively advanced instruction designed to foster the initiative and adaptability of the trainees, to maintain their specialized skill of production, and to keep alive their faith in themselves as valued members of the community. In short, the courses would be designed to prevent these men from deteriorating while awaiting fresh employment. If this is not done they will quickly become unemployable.

Training for Leisure.—The second major problem confronting the educational world of to-day is that of training citizens so that they will be able to employ their leisure time usefully. In the past this problem of leisure has been of considerable importance only in the case of citizens who had inherited wealth or ones who were destined to rise to positions of responsibility and authority.

Under old conditions the rank-and-file workers were usually compelled to spend the major part of their lives either at work or in resting prior to another day's toil. Recently, however, there has been a considerable amelioration of working conditions for this large section of society, so that quite apart from any complications that may arise from periods of unemployment the problem of educating these men for leisure has become of increased importance.

Previously all free time was required for rest, now some of it can be profitably utilized.

But at this point it is desirable to enquire why the nature of a man's leisure occupations is of importance in the modern world. Undoubtedly the chief reason is that education for work develops only one side of any human being, and under modern conditions this development is of an increasingly specialized nature. Thus unless the educational policy of a community is to be directed towards the creation of bands of specialist workers, whose activities are to be co-ordinated by some small group of intellectually trained leaders, it is necessary that education for work should be supplemented by instruction in those broader aspects of life which the citizen may develop further during his leisure periods.

Otherwise the development of a worth-while civilization becomes impossible, for no community can hope to advance throughout the centuries if it is composed chiefly of men and women who are merely complicated, automatic machines. For progress it is essential that the majority of the community should be vitally

interested in problems with a social as well as an industrial background.

Apart from this problem of ensuring the development of civilization the nature and extent of the cultural background of citizens is of great importance in any modern community, since it plays a most important part in controlling the relations between the various industrial and professional classes.

Even in the most democratic countries a considerable gulf exists between the general body of workers and those citizens who have been fortunate enough to secure positions involving a certain degree of authority or responsibility. Actually this gulf is of a dual nature, being due in part to the stratified nature of the works' organization, and in part to social conventions and distinctions.

Up to the present this dual nature has not been sufficiently realized, and prominent educational administrators still appear to believe that the workers' dissatisfaction with their existing status in the community can be cured by increased facilities for technical education. Admittedly the provision of such facilities will result in certain ambitious members of the rank-and-file rising more quickly than they otherwise would to positions of responsibility in the works organization; but it must be realized that, irrespective of the general level of technical education, the majority of the workers of the world will remain engaged on work of a routine nature, while only a small proportion will rise to positions of authority.

Consequently it is futile to endeavour to raise the workers' opinion of themselves solely by an increase in the technical side of their education. As a body they will still have to spend their working time controlling the actions of machines while they themselves are controlled by men of superior authority. Indeed, if the inferiority complex of the workers and the superiority complex of the controllers are to be dissipated it will be necessary to utilize some method in addition to that of increased technical education; and to appreciate the nature of this required procedure the dual character of the gulf between these two classes must be realized.

To a large extent the worker feels a sense of inferiority, not because his work is of a manual nature while his overseer's work is chiefly mental, but because normally his intellectual powers have not been sufficiently developed to enable him to enjoy taking part in the social life and leisure pastimes of the other class. In most cases the general education has ceased at the age of fourteen years. Since then he has been engaged exclusively on specialized technical work during the day, and possibly on similar studies at night, thus leaving little opportunity for the development of general intellectual interests.

As a result his outlook is warped. If he is to become a really effective social unit capable of co-operating with other sections of the community it is essential that he be given an opportunity to continue his general education to a later date than is now generally the case. Unless this idea is embodied in the general educational policy it will be impossible to remove class distinctions, for one cannot create a spirit of tolerance and goodwill between the various members of a community unless they all have cultural backgrounds of approximately similar content.

Thus both from the point of view of reducing unemployment, and also from that of educating the rank-and-file of the community for leisure, it is desirable that the school-leaving age should be raised above its present level. As will be shown later the trend of developments in industry is now such that the school is gradually replacing the workshop as the location for specialized industrial training.

For these varied reasons the importance of the fourteen to eighteen-year period as a time for education rather than for work is continually increasing. But if these years are to be effectively utilized for real education it is essential that very careful consideration be given to the content of any courses that may be set up in this period. For example, since it is necessary that all such instruction should aim primarily at training citizens and not merely at producing skilled artisans, these courses should all contain a substantial, cultural core of general education.

Again since this type of education will usually be leading to employment in either industry or commerce the vocational aspects of the programme should become increasingly important during the later parts of the training, but this must be done without cramping the cultural side of the work.

Finally since the demand for recruits for industry and commerce is liable to fluctuate over wide ranges from year to year it is desirable that the organization of the later portion of the training should be as elastic as possible in order to facilitate the change-over from school to employment. Thus it is desirable that the scheme should make it compulsory for all youths to remain at a full-time school either until they reach an age of 18 years or until such time as they are recruited into industrial or commercial employment of an approved character. Further it should be provided that the legal minimum age for such recruiting should be at sixteen, and that in the event of youths entering employment during the 16-18 year period they should be compelled to complete their full education on a part-time basis.

Chapter V

ORGANIZATION OF SECONDARY EDUCATION

IN view of the increased importance of continuing the education of all citizens up to an age of 17 or 18 years it is desirable to review the factors which should govern the organization of this section of the educational scheme.

Chief amongst these is the fact that every scheme of secondary education should be organized with a dual objective. In the first place it should develop in all students a full sense of their responsibilities, duties and privileges as citizens of a common State. This aim should permeate all sections of secondary education. But parallel with this primary aim each particular section of the scheme should be organized to train its own students for the special responsibilities associated with their chosen form of life work.

Thus secondary education divides into a number of principal subsections, such as education for industry, for commerce, for agriculture, or for one of the various professions, and each of these subsections requires an individual emphasis of its own. At the same time they must be co-ordinated so that the training of students for effective citizenship will remain their basic and common objective, so linking the specialist sections into an organic whole.

This forms the first essential in any scheme of secondary education; but for real success adequate consideration must also be given to a group of problems associated with the selection by individual students of an appropriate type of secondary training. Here the first requirement is that the average student will have reached an age at which he will show some definite aptitude for one of the available classes of work before he, or his parents, are called upon to make a definite selection between the several types of secondary education. If the scheme forces a decision at an unduly early age the efficiency of the State will be considerably reduced through the large number of misfits produced by the educational system.

This probably constitutes the greatest inherent defect of the educational systems of certain European countries, such as England, for there the nature of a student's further education is determined at the age of eleven years. At this early age few students show any marked preference for a particular type of work, and so it is very unlikely that a classification made at this age will prove really satisfactory.

In the past the whole question of age of choice has been dealt with on a rather empirical basis, and the selected age has fre-

quently been determined mainly by the fact that industry has demanded that its recruits should be relatively young. Even now there is little real information available on this whole question. Consequently it is desirable that considerable attention and research work should be devoted to it, for the State cannot afford to retain an unsatisfactory selection system. Even if only a small percentage of the potential intellectual leaders are thereby condemned to lives of routine industrial work it will finally cost the community very dearly.

A second and allied problem is that of assisting students and parents in making an intelligent choice between these several types of education. Here reference is made not to the problem of deciding whether a youth is to be a machinist or an armature winder, but rather to that of deciding whether he should be educated for commerce, industry, agriculture, or one of the professions.

Here again educational progress is retarded by the present inadequate knowledge of the factors that make for success in each of these spheres, and of the intellectual signposts that indicate the presence of these qualities in a student of relatively immature years. However considerable advances have been made recently in the practice of psychology, and there are now indications that a satisfactory system of aptitude tests may be developed in the reasonably near future.

At the present time the selection is usually determined by such factors as the expressed desire of the student or of his parents, the financial position of the family, the adviser's personal knowledge of the physical characteristics required for each type of work, and his estimate of the probable number of recruits needed by each section.

Unfortunately the information available on this last point is usually very inexact; but once the importance of avoiding the overcrowding of one section at the expense of another is realized this problem should be easily solved, for it involves only an investigation of a mathematical nature. For example the pro-fessional section of American engineering has recently been su-jected to a close scrutiny which showed that an annual entry equal to 3½ per cent. of its existing membership was nec to maintain this professional group against losses caused and retirement, while an additional entry of 1½ to 2 p necessary to provide the gradual expansion in th that was required on account of population incre of the gradually increasing sphere of activity profession.

However, it must be realized that even under the best possible conditions some students will be placed in unsuitable sections of the secondary scheme of education, and so adequate provision should be made to facilitate the transfer of these students at later stages in their education. This naturally necessitates close co-operation between the various types of secondary education, and increases the desirability of maintaining a common core of general studies throughout all the sections. Further it is necessary that the entry into the later years of any course of study should not be governed by a too rigid system of pre-requisites.

The observance of these general principles will facilitate the transfer of educational misfits; but, if the scheme is to be complete, provision must be made for the maintenance of an adequate system of bursaries or scholarships for the support of brilliant students who are transferred into the professional type of secondary education. In this branch full-time studies may have to be continued till the student is 19 or 20 years of age; and if scholarships are not provided a large proportion of these specially selected students from other secondary sections will be unable to complete their professional training, since their parents will lack the necessary financial resources.

Specialization in Secondary Education.—In an earlier section mention has been made of the dual objectives that should characterize each branch of secondary education, and of the fact that a certain degree of specialization was desirable in each branch. It is now necessary to draw attention to the ever growing demand for the introduction of a highly specialized type of secondary education. This tendency is most highly developed in the technical branch, probably on account of the fact that for a long period this division has been carried on with very little relation to the other sections of secondary education. However the problem also exists to a lesser extent in other sections. In all cases the specialized approach is open to two grave criticisms.

In the first place any increase in the degree of specialization will make it more difficult for students to transfer from section to section after having commenced their secondary education, and so cause an increase in the number of educational misfits in the community. Even more important still is the fact that increased specialization invariably causes a progressively decreasing importance attached to the general side of the educational process. Since the control of any specialized system gradually falls into the hands of enthusiastic specialists who ... a personal experience of the benefits associated ...ation, and so fail to realize its value. Conse...o willing to accede to the persistent pres-

sure exerted on all secondary educational systems by parents and employers who favour the introduction of instruction with an immediate economic value.

In the past this tendency towards specialization has been counteracted chiefly by the fact that students usually desire to obtain some publicly recognized certificate as evidence of their training, and in the non-technical sections of British secondary education the award of such certificates has been controlled by the Universities. Consequently the syllabuses of these sections of secondary education have tended to conform with the requirements of the University examiners, and originally these emphasized the importance of the general rather than the specialized type of studies.

However, at the present time a large body of teaching opinion is in opposition to this University control on the grounds that it stifles the life of the secondary schools, and gives undue consideration to that relatively small section of secondary students that intends to take up University studies.

Indeed some teachers now feel so strongly on this question that they advocate breaking away from the University control, so that their teaching programme could be designed primarily to train students for the problems of home life or of business activity. Such tendencies are to be regretted, for actually there should be a very close correspondence between the types of training required for a successful business or home life, and that needed as the basis of a University career; but the fact that such proposals are made shows that all is not well in the relations between secondary schools and the Universities.

Admittedly a considerable gap now exists between the types of training that are commonly regarded as suitable for these several fields; but this is due principally to the fact that recently both the industrial world and to a lesser extent the Universities have been afflicted with an undue admiration of specialized training. Consequently both bodies have tended to lay their major emphasis on the specialized aspects of their entrance requirements, while less importance has been attached to the general cultural training that should form a common core to both types of training.

Now the position has been reached that a section of educational opinion advocates the establishment of separate systems of secondary education as preparation for a University, business or home career. It would however be unfortunate if this solution of the problem were forced upon the community for the adoption of such a sectionalized layout of secondary education would undoubtedly lead to an increased stratification of society, and so would conflict with one of the primary objectives of all true education.

Therefore it is essential that strenuous efforts should be made to displace the fetish of specialization from its present position, so that a single, general type of secondary education may be developed which will serve as an adequate training ground for the home, for industry, and for the professions.

So far the technical branch of secondary education has remained outside the influence or control of the Universities, and under these conditions it has developed along highly specialized lines, which have had little contact with the work of the general section of secondary education.

Indeed technical education has on the whole tended to neglect the important influence that a sound education in general subjects should have on the social outlook of industrial workers, and in many cases technical instruction has been regarded as a branch of industrial activity rather than as a component part of the educational system of the land. For example in Belgium the technical training is controlled by the Department of Commerce, since it is believed that this will keep the training in the closest possible touch with the requirements of industry, and so ensure the correct number of suitably trained recruits.

From the industrial point of view such a system is effective, but it is very unlikely that it will pay sufficient regard to developing the personality of its trainees. Indeed, it is most probable that in such an organization personal interests will be subjugated to those of industry, so that the efficiency will be obtained really at the expense of the individual.

Admittedly the divorce between the technical and general sections of secondary education is not always so pronounced as it is in the above example; but in most lands the relationship is a rather loose one, and usually the effective general education of youths who are to be rank-and-file workers ceases when they reach an age of fourteen years. From then on their whole education is predominantly industrial in nature and outlook, and affords the trainee little or no assistance in forming an intelligent view on general problems of social and national importance.

Thus one of the chief problems now facing educationalists is that of bringing together the technical and general branches of secondary education. These should form complementary parts of a general scheme in which the primary aim would be the creation of informed citizens rather than the training of recruits to meet the specialized demands of any sectional interest.

Indeed the ultimate objective of such a scheme should involve the avoidance of all specialized training during the secondary educational period; but, as this is not yet possible, a desirable initial step in this direction would be to postpone all specifically

technical instruction until the student has completed at least two years of general secondary education. However the adoption of even this partial unification of all branches of secondary education is beset by considerable difficulties. For example it would necessitate a broadening of the scope of secondary education, so as to include manual as well as mental training. This would involve a consequent reduction in the standard of the theoretical work as compared with the present levels and so would necessitate a readjustment of the entrance requirements of the Universities. Also the adoption of the scheme would prevent youths being recruited into industry before they had reached an age of sixteen years, and this would be strongly opposed by many industrialists.

But in spite of these objections the scheme has certain inherent advantages which make its adoption most desirable. In the first place it would considerably strengthen the general cultural background of all sections of the community, since youths would remain in a cultural atmosphere until they reached a relatively mature age. In addition it would reduce the sharpness of class distinctions, as it would then be no longer necessary to segregate the youths of from 13 to 16 years of age in different groups according as to whether they were destined for a vocational or a professional type of career.

Chapter VI

FINANCIAL SUPPORT OF EDUCATION

ALTHOUGH a discussion of the detailed financial arrangements involved in the support of the educational system is beyond the scope of this report it is nevertheless desirable to include a brief review of this general problem. The proposals made in the earlier sections could not be adopted without a considerable increase in the total educational costs, and so the general problem is approached chiefly from this aspect.

The suggestion which would have the greatest effect on the cost of education is that of raising the school-leaving age. This would increase the school population quite considerably, thus involving the authorities in added expenditure for staff, equipment and buildings. Further expense of a similar nature would be consequent upon the adoption of the suggestion that men whose original skill has been rendered valueless by the general adoption of new processes should be trained for new livelihoods.

But in addition it must be realized that an increase in the school-leaving age would postpone the date at which youths would be self-supporting. Thus this change would place an added financial responsibility on the heads of families, and in many cases this would unduly lower their standard of physical comfort. Consequently any increase in the period of compulsory schooling should be accompanied either by the establishment of a widespread bursary system, or by the introduction of a child endowment scheme for families with relatively low incomes.

In the past education has drawn its financial support from several sources (such as the State, religious bodies, past-students, parents, and private benefactors). In any scheme for expansion efforts should be made to increase the income from each of these sources, but the possibility of opening up fresh resources should also be fully investigated. Recently the State has been the chief financial support of the educational system, and since the proposed advances in the system are of a universal nature it is equitable to expect that they should be financed chiefly from the general tax fund. But as a safeguard against the development of an autocratic State control it is desirable that the non-State organizations should at least maintain their relative position in the educational scheme.

Therefore it is desirable that efforts should be made to build up a tradition amongst past-students that they are definite debtors to the educational system, and that it is their privilege to contribute voluntarily towards its support during their later life. It is also

important to realize that past students can assist in the financial support of education not only as individuals but also as groups. To a certain extent this is already occurring since certain national associations of professional workers now finance educational schemes that are of particular interest to their oncoming members. The last student can also frequently assist in a co-operative way by supporting the educational activities of the religious organizations.

Turning now to possible fresh fields it appears that industry is the one which can most equitably be called upon to meet part of the additional educational costs. Actually this field has already been entered by some countries, such as France, but up to the present Australian industry has not been called upon to make a direct contribution to education. The employers as a class have a dual debt to the educational system, as they themselves have benefited from its activities during their earlier years, and in addition their continued prosperity depends on whether or not they can fill their business staffs with well-educated men. This field of financial support should be of importance for all branches of secondary education, but is of special significance in connection with the technical field.

If employers should not respond of their own volition to the schools' call for additional support there would be good grounds for the State laying the obligation upon them. Naturally such a suggestion will be opposed by many employers; but the general underlying principle has already been recognized by some countries, and it is certain that its wider adoption would be of considerable benefit to the community as a whole. In the first place this action would materially increase the financial resources of the educational system; and secondly the impost could be so arranged that it would make employers pay more attention to the training of their own recruits and to maintaining the general adaptability of their workers. A good example of such a tax is found in France, where employers are directly taxed to finance certain aspects of the industrial education.

Actual cash payments by individual employers do not represent the only way in which industry should contribute to the support of education. In many lands such corporate organizations as Chambers of Commerce assist in the educational work by maintaining training schools. In other cases individual firms or industries give valuable assistance both by donating equipment for technical schools and by maintaining schools for their employees. Such assistance can be of very great value, and it is to be hoped that these activities will be increased greatly in the future.

The manner in which the State itself can best assist in financing a system of universal secondary education is best appreciated from a review of the benefits that the community as a whole would enjoy as the result of such a scheme. From a long-range point of view the chief advantage accruing to the community would be the more adequate cultural background that its citizens would obtain. Thus the civilization of the State would be advanced. In addition to this effect there are certain others which, although of less final importance, are more immediate in their effects on society. These relate chiefly to the ways in which the troubles of unemployment can be reduced by an extension of compulsory education, and have already been referred to in some detail.

In view of these important connections between the school-leaving age and the unemployment position it seems appropriate that the State controlled "unemployment relief funds" should be utilized at least in part to finance a lengthened period of education for all citizens. At present the conditions are particularly favourable for the adoption of such a policy. Most lands have organized unemployment relief schemes during recent years, and as the need for actual relief is now gradually decreasing these funds will show an increasing surplus which could well be made available for general educational work as an insurance against the recurrence of mass unemployment. Naturally many will rebel at the suggestion that these "emergency" taxes should be continued even in part after their immediate need has disappeared; but it must be realized that unless remedial steps are taken during times of returning prosperity the community will quickly be faced with further periods of mass unemployment. Industrial depressions will recur periodically for many years to come; inventive genius will continually replace manual labour by machines. Thus the community must endeavour to protect itself against the worst aspects of these phenomena. Continued education provides a possible and desirable solution, and so the community should be prepared to pay the cost involved in this forward step.

PART II

INDUSTRIAL EDUCATION

CHAPTER VII

AIM AND DEVELOPMENT OF INDUSTRIAL EDUCATION

The Aim.—In addition to the general cultural training which should form the real basis of any educational system it is also necessary that this organization should provide facilities for training each citizen for some particular type of life work. In life it is usually the nature of a man's work that tends to divide him off from other individuals, for these duties must of necessity differ widely from group to group in the community. Thus it is natural to expect that the technical training provided in any educational scheme should be of a relatively specialized nature. But if the community is to obtain the best possible results from its educational activities it is essential that the technical work should be so organized that it will not tend to undermine or destroy any appreciation of culture that may have been developed in students by their general studies. Thus technical education should have a twofold objective. Firstly it should conserve the cultural interests of its students, and secondly it should train them for some rather specialized activity in the working life of the community.

At present it is most essential that this fact should be realized by all educationalists, for there are many industrialists who hold the view that specialized technical instruction is all that is either necessary or desirable in a scheme of technical education. Further in most authoritarian states efforts are made to restrict the development of independent thought on general subjects, and at the same time considerable emphasis is laid on the absolute necessity for improving the immediate competitive power of the industrial organization. Thus it is natural that the authorities of such countries should favour the adoption of a highly specialized programme of technical studies as the basis of their industrial education. Recently this authoritarian mode of government has been accepted by a surprising number of communities. Individuals who believe that in the final analysis it is cultural resources rather than mere mechanical efficiency that make a country of importance in world affairs would therefore be well advised to keep their views before the public in a convincing manner.

Development of Industrial Education (for rank-and-file workers).—Under present conditions it is necessary to distinguish between industrial education for the general body of workers and that for men who are finally to occupy the higher positions in the industrial organization.

Originally this distinction between the education of leaders and that of rank-and-file workers was not so pronounced, for under the early industrial conditions each of these classes received practically the same technical training. In those days all industrial work was based on craftsmanship, and so the apprenticeship system where master and pupil were in constant and intimate contact over a long period was the ideal method of imparting a knowledge of traditional trade methods, and of developing the manual skill and designing instincts that were necessary in all real craftsmen. It was a slow and unhurried procedure in which the personality of the master was probably as important as his craftsmanship, for his duties included much more than merely training his apprentice in the skill and mystery of the craft—indeed the whole mental attitude of the pupil was largely developed by his contact with his chief.

In those days apprenticeship was a training for life, and not merely a preparation for industrial production. However, with the introduction of steam power, and the development of the factory system, the position was radically altered. Businesses with large bodies of workers were established, and their employees had little or no contact with the actual employers. Indeed in many cases the employer was no longer an actual producer skilled in some craft or trade, for ownership gradually passed to men skilled in the problems of finance and distribution. These delegated the control of production to foremen and managers.

Thus that personal contact which had been the life-blood of the apprenticeship system was lost within a few years of the introduction of steam power; but in spite of this the skeleton of the old training system was still retained. This was due partly to the conservative nature of mankind, but an additional reason was that the apprenticeship system stabilized the labour supply by legally binding recruits to their employers for a period of years. But the retention of apprenticeship under these new conditions was a great mistake, for it quickly ceased to have any real educational significance, and became merely a method of training youths in mechanical skill and manual dexterity.

As the financial complexity of industry increased this unfortunate tendency was accelerated through the gradual replacement of personal owners by such impersonal agencies as the public company. This change in control should certainly have caused a thorough revision of the apprenticeship system; but through the general apathy of public opinion no effective steps were taken until many years later.

In the meantime certain other influences had been actively engaged in undermining the tradition that industrial recruits must

of necessity be trained in the workshop under the terms of a rigid apprenticeship. Chief amongst these was the increasing importance of science in many of the newer industrial processes. Indeed, once a process became based on science it was no longer possible for its recruits to be instructed solely in the workshop since this unit afforded no facilities for scientific studies. Consequently with the growth of the chemical and electrical industries the workshop ceased to be the exclusive training ground, and in English-speaking countries a tradition arose that the works should retain the practical side of the education while the theoretical work underlying the processes should be transferred to some type of school.

This tendency to transfer the training of recruits from the works to the schools was also favoured through the application of mass-production methods to industrial processes, for the financial success of these methods depends on maintaining a certain predetermined rate of production. This becomes impossible if recruits are trained in the actual works since their slowness upsets the production schedule. Also the machines that are utilized are usually very complicated and highly specialized units which, from an educational point of view, are quite unsuitable for the instruction of trainees. Practice on such machines will undoubtedly produce satisfactory machine-attendants; but it will also dull their adaptability and resourcefulness; and at the same time it will teach them little or nothing about the methods underlying the production of the given article.

And now with the ever increasing use of automatic machinery the supremacy of the workshop as the training ground is being challenged from another direction. Investigations show that while the percentage of skilled men required in an industry does not usually alter much as the processes are changed from a manual to an automatic basis yet there is a very definite change in the type of skill required. With manual production the skill required is primarily an ability to use tools; but with automatic machine methods manual skill becomes less important. Indeed it is largely replaced by such attributes as general intelligence, an appreciation of the functions of the component parts of machines, an ability to understand and adjust complicated equipments, and an ability to develop new interests and to perform unusual jobs efficiently.

Thus the new type of skill is based primarily on intellectual adaptability, resourcefulness, and an ability to master new situations. Consequently the general tendency is now towards developing the school rather than the workshop as the basis of a modern technical education.

The accuracy of this statement is amply indicated by a review of the history of industrial education in England.[1] In 1825 the voluntarily supported Mechanics' Institutes formed the sole avenue through which English workmen could obtain access to technical information. Then towards the middle of the nineteenth century government assistance was given to Art Schools and to Science Schools, which gradually began to play an important part in training men for some branches of industry. However, at that period employers were definitely opposed to technical education—partly because of tradition and partly because they feared the competition of trained men—and so the growth of these facilities was slow.

Towards the end of the century the increasing pressure of foreign manufacturers in the export fields caused British employers considerable alarm. Investigations revealed that this competition arose chiefly from lands with well developed schemes of technical education and this caused the British authorities to increase the importance of the school in their schemes of industrial training. The local authorities were empowered to raise funds for school buildings, and a part-time scheme of technical education was organized on a voluntary basis.

In 1902 the status of these schools was further increased by an educational reorganization which placed all sub-University instruction under a single authority in each local district. This marked an important stage in the development of the British technical school system, and during subsequent years this section of the educational work advanced greatly. Originally employers were opposed to these school activities, but recently they have become much more sympathetic. Consequently it has been possible to greatly increase the scope of part-time evening schools, and to introduce a certain amount of day instruction for employees. It is, however, important to note that practically all this instruction is of a part-time nature. During recent years there have been two developments of outstanding importance. The first is the growth of 'Junior Technical Schools.' These are full-time day schools, and divide into two classes. In one the work takes the form of a pre-apprenticeship course for youths between the ages of thirteen and sixteen, and has the dual aims of continuing their general education and of facilitating their entry into industry. In these courses the technical instruction does not take up the major part of the student's time, nor are the courses designed to prepare students for any particular trade, but rather for some broad branch of industry, such as chemistry or engineering.

1. For further details see Board of Education, Educational Pamphlet No. 49.

In the other class of junior technical school the aim is quite different. Each of these trains youths for some specific trade, and the courses are designed to entirely replace the works' type of apprenticeship. Actually these courses are modelled on the French *écoles d'apprentissage*; during each year of the course twenty out of the thirty weekly hours are devoted to actual practical work in the schools' workshops. Consequently relatively little time is available for general subjects. At present few of these schools have been established outside of the London area, but efforts are being made to extend this type of training.

The second major development in this period is the growth of part-time day classes at the technical schools, in addition to the well-established evening courses. Under this day-instruction scheme a growing body of employers allows selected apprentices to take time off on pay to attend the classes of the local technical school. Initially employers were very much opposed to this idea; but this opposition is gradually breaking down, and in some industries an appreciable proportion of the apprentices are now trained under this scheme.

As has already been mentioned British technical education is organized mainly on a part-time basis, and is supplementary to a works' apprenticeship. In many Continental lands the organization is entirely different, and usually aims at providing technical education on a full-time, pre-employment basis.

In France[2] although apprenticeship was originally the only mode of entry into any of the skilled crafts or trades the importance of the school as a supplementary method of training was realized rather earlier than it was in England. A number of manual schools for apprentices were established as early as 1873. However it appears that the proportion of apprentices attending these schools was fairly small; and it was only in 1919 that a determined effort was made to provide a sound training for all persons who desired to become skilled artisans.

To a considerable extent this decision was due to the experiences of the war years; but a further factor was the realization that the industrial position of France could not be maintained during the coming years of population decrease unless all workers were adequately trained. Consequently the loi Astier of 1919 provided that all young workers should attend instruction courses for from 4 to 8 hours per week, and in certain cases provision was made for these classes to be held during normal working hours. The

2. For further details see *Report and Investigation of Engineering Education*, Vol. 1, pp. 758, 824, by Soc. for Promotion of Eng. Education, U.S.A.

importance of these training schools was greatly increased in 1925, since in that year a pay-roll tax was imposed on all employers to provide revenue for financing full-time apprenticeship schools, part-time vocational courses, and bursaries for needy students.

The full-time apprenticeship schools (*école practique,* and *école de métiers*) recruit their students from the elementary schools at an age of 13 years, and every effort is made to reproduce a works' atmosphere. The weekly hours vary from 44 to 54, and of these at least half are spent in the school workshops under instructors whose qualifications approximate to those of foremen. The remainder of the time is taken up by general education which is carried out by highly qualified teachers, for although the primary object of these schools is to produce hard-working craftsmen the authorities also desire to give the students a general education. At the conclusion of this training the students enter industry with the status of improvers.

Thus the French policy is to develop a full-time, pre-employment system of industrial education, in which a works apprenticeship will be replaced by a school training. Similarly in Belgium the *écoles professionnelles* are being developed with the object of replacing an instruction at the works by a school apprenticeship.

In a review of this nature the case of Czechoslovakia[3] is of interest since the educational organization of that country has been built up in post-war days. Here the system of industrial training embodies both the works and the school type of instruction; but the policy is to delete the works' instruction in all industries where manual work is being replaced by large-scale operations. In these industries trade schools are being organized for the various trades and crafts, and in 1930 some 11,000 students were being trained in this type of full-time school.

In addition to these trade schools provision is also made for all apprentices to attend day-continuation schools during working hours. These classes occupy eight hours in the week, and it is interesting to note that the employers can be fined if their apprentices do not attend regularly.

Thus it appears that at the present time the school method of instruction is playing an important and growing part in the training of industrial recruits. The work of the schools now embraces not only general cultural subjects but also often includes actual training in workshop methods. Thus the school is definitely challenging the works as the location of industrial training, and at the same time the apprenticeship system of training is being subjected to an ever-increasing barrage of criticism. These

3. For further details see *Trade Schools on the Continent*, p. 69. H.M. Stationery Office, 1932.

criticisms divide into three main groups according to whether they are based on shortcomings in the scheme itself, or are due to the attitudes adopted towards the scheme by employers and trainees respectively.

Chief amongst the criticisms falling into the first group is the fact that the scheme has lost its efficacy as a means of improving the general education and social outlook of the trainees. Another shortcoming is that the works' atmosphere is not suitable for training students in the basic scientific facts that are of ever increasing importance in modern industrial processes. Again, for the reasons already outlined, trainees cannot be efficiently instructed in a workshop where many of the processes are carried out on a mass-production basis.

The conservative outlook of many foremen is another disadvantage since many apprenticeship schemes are administered largely by these officials. The chief trouble here is that the training often tends to perpetuate old methods instead of preparing the new workers for the conditions that will hold during the fifteen or twenty years following the completion of their apprenticeship.

In other cases the value of apprenticeship is reduced through the variation of training standards that occur in different works. Most of the courses are also unduly prolonged. This is due partly to the conservative outlook of many employers and foremen; but the chief reason is that the works no longer provide a suitable atmosphere for the modern type of training.

In addition to these shortcomings which are inherent in the method itself existing apprenticeship schemes are handicapped by the attitudes adopted by many employers. Here the greatest trouble is that on the occurrence of an industrial depression most employers tend to reduce the number of trainees whom they will sign on. Thus a few years later industry suffers from a lack of skilled workers. The position is further complicated by the fact that a certain number of employers regard their apprentices merely as a convenient supply of cheap labour rather than as the source of future skilled workmen, and so make little effort to ensure that the youths receive an adequate experience of manufacturing methods. A further trouble often arises in cases where the apprenticeship system is worked in conjunction with technical school training, for some employers and a larger number of foremen object to the apprentices being allowed to take time off during shop hours to attend school classes. They point out that this concession tends to disorganize production schedules.

Finally the efficiency and popularity of the apprenticeship system in certain lands is suffering as a result of the fact that youths object to being legally tied to a master for a number of

years, and so do not co-operate wholeheartedly during their apprenticeship period.

In the case of industries where handcraft is still predominant the majority of these shortcomings could be overcome by the general adoption of a system of part-time continuation education in general and scientific subjects. This school work would be conducted during normal working hours and would be supplementary to a liberally administered system of works training. But in industries where large-scale production has been adopted it is essential that recruits should receive their technical training in schools somewhat resembling the Junior Technical Schools of England or the French apprenticeship schools.

In these institutions adequate facilities would need to be available for instruction in scientific and general subjects as well as in the more vocational sections of the training. Further, it is essential that these schools should be administered with the object of developing the mental alertness, adaptability and resourcefulness of their trainees in preference to merely training them in craftsmanship and the traditional methods of production. Otherwise the rank-and-file of industry will not be able to play a really effective part in the life of the community.

Training for Industrial Officers.—When attention is turned to the education of those individuals who aspire to occupy the more responsible industrial positions, the importance of the school as the training ground becomes more marked. A knowledge of modern science is as yet a necessity for only a fraction of the general body of workers, but this type of knowledge is essential for all who wish to enter the higher positions.

In England this distinction did not develop until some considerable time after the adoption of steam power. This was due chiefly to the conservative outlook of British employers and Universities, for the former held that scientific knowledge was unnecessary, and the latter refused to include scientific studies in their curriculums.

However in France[4] the importance of providing adequate scientific training for those seeking appointment to the higher industrial positions was appreciated at a relatively early date. Indeed in the engineering section a special training school for professional officers was established as early as 1747, while by 1795 a central professional school—the École Polytechnique—had been founded with the object of raising the intellectual and scientific standards of men who intended to enter the technical sections of the Public

4. For further details see S.P.E.E. *Report on on Investigation of Engineering Education*, p. 758.

Service. The curriculum of this college included such subjects as mathematics, mechanics, descriptive geometry, architecture and chemistry; and its students were carefully selected with a view to obtaining the men "who knew the best rather than those who knew the most."

Similar schools for private industry were founded a little later, and by the middle of the 19th century the higher sections of French technical education had developed to such an extent that her industries succeeded in overcoming the lead that inventive genius had conferred upon the industries of England in the early stages of the Industrial Revolution.

In Germany a similar realization of the importance of the school in the training of professional officers for industry occurred during the years that followed upon her defeat by Napoleon. At that time Germany's leaders determined to transform the existing agricultural population into an efficient industrial nation, and in this crusade they quickly realized that apprenticeship and pupilage were inadequate tools for training professional officers. Consequently a complete system of technical schools was gradually created in order to provide an adequate education for these recruits.

Initially the work of these "technische hochschulen" was not very advanced, because they had to draw their students from the primary schools; but with the establishment of adequate secondary education for industrial recruits these schools gradually raised their standards till finally they reached full University rank. During the early part of the 20th century the status and reputation of these institutions was greatly increased as a result of the leading part that they took in the development of German industrial life; indeed, the research work that they initiated during this period stamped them as the greatest creative agency in their country.

It was indeed the success of these French and German methods of education that caused the English authorities to take an increased interest in the school as a training ground for senior industrial officers, and this finally resulted in numerous technical courses being established in British Universities. Initially this step met with very little support from the British public; but now even this stronghold of conservative tradition is beginning to admit that the broadly scientific and cultural education of the school and University has certain important advantages over the essentially practical training of the works. Consequently it is probable that a gradually increasing proportion of the responsible industrial positions will be filled by University trained men.

CHAPTER VIII

CLASSIFICATION OF TECHNICAL EDUCATION

THE complexity of industry necessitates some form of subdivision in technical education. One feasible mode of classification is on the basis of the function of the individual in the industrial organization. On this basis industry divides into such groups as rank-and-file workers, foremen, works managers, and technical experts. An alternative criterion is also available which groups the various trades into two main sections according as to whether their processes are of a scientific or an empirical nature. In technical education it is convenient to utilize both of these criteria as bases of classification.

Training for Scientific Trades.—For scientific trades the school work is normally based on a fairly full training in mathematics, and in the scientific facts and laws that are definitely related to the work of the industry; this is supplemented by laboratory experience in the experimental procedures underlying the works processes. In addition a limited amount of actual workshop or laboratory experience with the simpler industrial processes is frequently included. In these industries little difficulty is experienced in building up satisfactory courses of school work for the more advanced types of workers; but there is a very real danger that the instruction for the rank-and-file will be unduly loaded with scientific subjects. In this connection it should be remembered that these men will always be engaged on work of a routine or possibly craft character. Consequently the chief reasons for including scientific instruction in their technical training are, first, to provide them with an incentive for keeping up their general education, and, secondly, to assist really ambitious men to rise to more responsible positions.

A factor which should be kept in mind when arranging courses for the more advanced sections of scientific trades is that these industries are frequently of a highly specialized nature. Thus their very existence may be suddenly challenged through some new invention or scientific development. Consequently it is necessary to ensure that at least a proportion of the better class students realize the importance of continuous research both as a weapon of defence and of offence. The training must fit these men to carry on such work in an intelligent manner.

Two conditions must be fulfilled before a scientific type of training can be successfully established as part of the educational scheme for a given industry. In the first place the theory of the

scientific processes which are involved in the practice of the industry must be reasonably well established; secondly, it is necessary that at least some manufacturing works should be willing and able to carry out their processes in a scientific manner.

Therefore, before any effort is made to establish a scientific type of training for a given body of workers it is essential that a careful review should be made of the relevant scientific information, and of the extent to which this is actually embodied in current industrial practice. Also since education should always be endeavouring to replace empirical training and processes by scientific procedures it is desirable that educational authorities should encourage research work in those industrial processes which are as yet in the empirical class.

Training for Empirical Trades.—In the case of industries which fall into the empirical group it is relatively difficult to develop a really satisfactory course of instruction. In most cases it is not practicable to deal with more than the properties of the materials, the empirical nature of the works processes, the characteristics and modes of construction of the mechanical equipment that is used in the works, and the routine testing of the products. This mass of data forms the real basis of the courses for all grades of workers, but the general emphasis is varied from course to course in order to suit the requirements of the various grades. For example the training for men who are aiming at responsible positions will normally include instruction in such subjects as costing methods, and works management; while in the case of rank-and-file workers the major emphasis will be laid on the actual use and maintenance of the process machines.

In the organization of courses of instruction for these empirical industries it is also necessary to realize that most actual production machines are not suitable for educational work, since they are designed with the object of obtaining a high output of the finished article, rather than of demonstrating to novices the detailed manner in which each step of the work is accomplished. Hence it is frequently desirable that the school instruction should not be given on normal machines. In such cases special units should be designed so that the student will be able to study how modifications in the machine affect the nature of the product. Also these instructional machines should be designed so that the work can be studied at each stage of its manufacture.

Naturally students who are trained on this type of machine will not be suitable for transfer to high-speed production work immediately at the conclusion of this training; but they will have some knowledge of the principles underlying the construction of commercial machines, and of the difficulties associated with the

manufacture of the goods. Consequently their adaptability should be reasonably high, and their training should make them something more than mere portions of the machinery that they are to operate. This idea of training students in the nature of the processes and in the functions of the various parts of the machines as a preliminary to any intensive training in the operation of commercial units is of great importance. Indeed in many industries it is desirable to go a step further, and to preface all machine work by a training in the manual processes that form the basis of the machine operations. In this way students can learn the actual nature of the various processes, and so will be better fitted to pass critical judgment on the output of the modern machines which they will afterwards operate.

Functional Subdivision of Courses.—Industrial education must also be subdivided so that it will fit in with the widely varying requirements of the functional groups in each industry. These groups vary somewhat from case to case; but normally the employees in any one industry can be divided into such groupings as tradesmen, foremen, production or works managers, technical assistants, general professional practitioners, and various specialist and executive officers.

Of these groups the first is the largest numerically. Its members are occupied primarily in carrying out manual operations, in supervising semi-automatic processes, and in maintaining the corresponding machines. Consequently the technical portion of their education must necessarily be directed towards improving their skill in these types of activity.

In the case of foremen the industrial education must also include a similar type of instruction, since the primary function of this group is to maintain the output of goods at satisfactory levels of quantity and quality; but in addition these men must also possess considerable organizing ability and a sense of responsibility towards their work. Consequently although their work is related primarily to the workshop their training must be broader than that of the tradesman, and should provide facilities for developing such personality and leadership as the trainees may possess.

These two groups form the great majority of the total enrolment; but in most cases it is also necessary to employ a certain number of more skilled workers who will generally organize and supervise the "production" or "shop" activities. These men are not usually concerned with the theory underlying a design; but they are interested in devising the best practical ways of putting certain jobs through the works. Consequently they are primarily

related to the practical side of industry. In the past these men have been recruited chiefly from employees who had received an essentially practical training; but recently it has been realized that they would do better work if they were also given a certain insight into the basic theoretical considerations that lie behind the designs of the jobs that they are to handle. Also it is desirable that they should be thoroughly trained in the drawing language of industrial practice.

In the larger works it is usually desirable to give the highly-trained technical staff a number of assistants to carry out the routine work that is incidental to the completion of any new development. Thus the draughtsman transforms the sketch design into the full working drawings that are required for the information of the foremen and the trade workers; again in chemical work there is a class of worker that carries out routine tests. The chief characteristic of the work done by members of this group of assistants is its routine nature, and so their technical training is normally of a vocational, as distinct from a professional, type.

But to ensure the continued development of any industry the activities of the trade and vocational workers must be supplemented by the theoretical work of men who have received a professional type of training. Normally this professional group can be divided into two sections.

The first contains those men whose work involves the theoretical investigation of developments that have been made possible by already discovered laws and facts, but seldom takes them into any field that is totally new to them. Consequently while their education must be of a high scientific standard it does not need to be so intense, nor so directed towards the development of personality, as that required by members of that second section of the professional group whose chief activity is the creation of new lines of constructive thought in problems associated with design, production, management and finance.

It is therefore necessary that the technical aspects of the education for each industry should be subdivided into three main sections—dealing respectively with the trade, the vocational, and the professional types of training. In addition it is desirable that two sub-types of instruction should be available in each of these groupings. Thus the general organization of technical education should be along the following lines:—

Types of Schools Required.—Firstly it is necessary to provide Trade Schools for instructing the body of tradesmen in general cultural subjects, in the reading of drawings, in the use of machine tools, and in the supervision and maintenance of automatic and

semi-automatic processes. Probably as time goes on the last phase of this training will become increasingly important on account of the replacement of hand work by automatic processes. The general reduction in working hours which will result from this increased mechanization of industry will make desirable an ever-increasing emphasis on the continued cultural education of these trainees.

But in addition to fulfilling this basic function these schools should also provide a somewhat more advanced type of instruction for the benefit of ambitious men who wish to fit themselves for positions involving a certain degree of responsibility. The chief differences required between these two levels of training would be in connection with the art of reading drawings, and in the degree of general adaptability imparted to the students.

The second main unit in the organization should consist of Technical Schools which would make provision for instructing both part-time and full-time students. These schools would have as their primary objective the training of production managers and technical assistants for the various branches of industry; thus the entry age should be kept relatively high so that their students would have an opportunity to obtain a satisfactory general education before entering upon the specialized industrial work. Normally these schools should also provide an additional, and rather lower, standard of instruction to meet the needs of men who wish to qualify immediately as foremen, but who have ambitions towards further study at a later date.

On this basis it would appear that schools of this type should set out to train men along the following lines:—

(i) They should give an outline of the principles underlying the chief manufacturing processes of the industry together with information as to the usual range of application of these methods. They should also outline the practical problems that are likely to be encountered in the application of these processes.

(ii) They should provide a thorough course in the preparation and interpretation of drawings with the object of training men who would be capable of producing satisfactory working drawings from sketch designs, and who would also be able to read a drawing with ease and accuracy.

(iii) Their programmes should include detailed information as to the chief properties of industrial materials and an outline of their usual spheres of usefulness.

(iv) Students should be given a thorough practical course in the use of machine tools with the object of familiarizing

them with the capabilities of the tools rather than of training them to a high degree of manual skill in high speed work.

(v) Finally the courses should provide opportunities for students to learn the art of supervising working processes, and to familiarize themselves with the methods employed in testing the products of the industry.

But in addition to fulfilling these requirements as to the desirable content of the courses it is also most important that these institutions should approach their work from the vocational viewpoint, rather than the professional one. In addition it is necessary that a close co-operation should be established between these schools and the corresponding industries so that the content of the courses and the techniques of the works may be satisfactorily correlated.

It is desirable also that the recruiting policy of the technical schools should be so oriented that they will attract those youths whose interests are primarily on the practical and production sides of industrial work, rather than those who wish to enter into the truly professional sections of industry, for the goal of the technical school course does not correspond with any intermediate point in a University course. Consequently if professionally-minded youths are drawn into the technical schools they will later experience a certain difficulty in transferring to the other type of training.

In addition to the types of training which have just been outlined in connection with the Trade and Technical Schools it is necessary to provide a truly professional training for the men who are to fill positions either as general technical practitioners or as leaders of industry. Normally this type of instruction is best provided by establishing technical faculties at Universities of high standing, and by organizing these in such a way that they will produce men who have a general rather than a merely technical education. Consequently their educational programmes should be kept as broad as possible, and should endeavour to develop the student's personality in addition to educating him in specifically industrial subjects. Further the training should familiarize the student with the scientific facts that underlie his chosen industry; and should develop in him an aptitude for applying the methods of mathematics and science first to the solution of physical problems, and later to the investigation of problems that arise in the particular industry.

But in addition to pursuing these technical and scientific studies it is necessary that the student should realize that certain responsibilities will devolve on him as a member of society. It will therefore be necessary for him to include the study of social and political problems in his scheme of post-graduate work.

Any University course that succeeds in obtaining these results will have achieved its primary objective, for it will have played an important part in advancing the general well-being of the community. If in addition it can implant in its graduates a desire to critically explore the existing practical procedures of industry through the medium of actual works experience the University will have succeeded in its secondary objective of improving the efficiency of the industrial life of the world.

Administration of a Graded System.—At the present time practically every industrial State has established schools in the trade, the vocational, and the professional spheres of industrial training; but the administration of these graded schemes of education varies widely from country to country.

For example, on the Continent of Europe the problems of technical education are viewed from a most realistic angle, and the whole educational scheme is usually administered with the primary object of increasing the industrial efficiency of the State. Thus in these countries the technical education system is designed to produce a large army of rank-and-file workers who will be efficient and industrious, a smaller body of highly skilled foremen, and appropriate numbers of technical assistants and professional men. Consequently entry into the vocational and professional types of schools is normally controlled by a system of competitive examinations, and the number of openings in each class of school is regulated to meet the needs of industry. Also although most of these States provide certain facilities for transferring promising youths to the higher types of schools at later stages in their education these schemes are usually planned on the assumption that this change-over should be limited to a very small proportion of the enrolment.

In England the position is different, for although the public authorities have established schools in each of the various grades of technical education they make no effort to control the number of students in any one type of school. Enrolment remains a purely personal problem which is not conditioned by any system of competitive examinations or of maximum entry quotas.

The chief reason for this is that the English regard any obvious or rigid control of educational facilities as a challenge to their democratic rights; but actually it is very doubtful if the English system is really any more democratic than the Continental one for in each case the final level of a youth's education depends primarily on the economic resources of his parents.

Actually the true test of the democracy of any educational scheme is whether or not it enables each student so to develop

his personality and his intellectual ability that he will be able to take his most effective possible part in the life of the community. Thus the adoption of logical schemes for the selection of suitable students and the prevention of undue overcrowding is not necessarily incompatible with democratic ideals. But on the other hand it must be remembered that the provision of adequate facilities for general education, and the maintenance of a liberal bursary scheme for the assistance of brilliant but needy students, are both essential factors in any truly democratic system of education.

An additional difference between the English and Continental viewpoints is that until recent times the English have tended to regard technical education as a publicly supported facility for the improvement of individuals, rather than as a method of advancing the industrial position of the land. At the moment this opinion is less firmly established in England than it was in earlier years, and it seems probable that the ever increasing competition of other industrial lands will finally enforce the general adoption of the Continental outlook. Indeed from certain published reports it appears that responsible administrators are already of this opinion. From the point of view of industry a development of this nature would be most welcome; but from that of the citizens in general it would be profitable only if the modified scheme laid sufficient emphasis on the importance of a prolonged cultural education as a necessary foundation for all sections of the graded technical work.

Probable Changes.—Thus it is to be hoped that the future will see a dual movement in the educational systems of industrial countries. On the one hand the period devoted to general education should be considerably increased, the scope of its subject matter should be broadened, and this work should be made the common foundation of all types of specialized study. On the other hand the graded nature of the specialized technical education which is superimposed on the general foundations should be increasingly emphasized so that the technical training for the various types of workers may correspond as closely as possible with the functional requirements of each class of work.

Admittedly there are certain serious problems associated with any intensification of a graded system of technical education, and the more important of these—such as the maintenance of relative standards, the selection of students for the different grades, and the organization of inter-grade transfers—will be considered in the following sections in conjunction with other general problems of technical education.

Chapter IX

PROBLEMS OF TECHNICAL EDUCATION

Maintenance of Relative Standards.

THE experience of overseas countries shows that the co-ordination and maintenance of appropriate levels of work in the various units of a graded system of technical education is not a simple matter. The equilibrium of the system tends to be upset by a variety of factors.

Probably the most potent of these is the desire manifested by the vocational section of the system to raise its standards of work in an endeavour to approximate to those of the professional section. Allied with this is the fact that the technical faculties of many Universities tend to develop courses that are unduly vocational in character, and at the same time fail to push on vigorously with the highest types of professional training and research.

The reasons underlying this latter tendency are important, since a general adoption of such an educational outlook by the Universities would finally have a very devastating effect on industrial progress. The urge for economy and balanced budgets provides the chief reason for this tendency since vocational instruction is easier to finance than is the truly professional work. Not only does it require less extensive equipment and staff for a given number of students, but in addition the less severe nature of the work usually results in an increase in the student enrolment.

The tendency towards a semi-vocational emphasis is also emphasized by the fact that as yet relatively few employers realize the advantage of employing men who have received a truly professional training. Actually the future prosperity of industrial undertakings depends largely on the appointment of a suitable proportion of these men to responsible staff positions, but this will entail the conversion of many employers. Until this change in outlook is brought about there will be a tendency for many Universities to provide an unduly vocational type of training in an endeavour to maintain their student enrolment at a high figure.

This trend towards a semi-vocational type of University training is one of the most serious problems confronting technical education, for the resulting lack of properly trained executive and research officers will finally prevent industry from functioning efficiently and progressively in the social organization. Also the public must realize that if an institution is to give an effective professional type of education it must not have to rely on fees as a major source of

income. Until the public fully appreciates this fact the Universities will be unable to play their full part in industrial education.

But even if the University work is maintained at a truly professional level the graded structure of the educational system may be rendered ineffective through changes in the outlook and objective of the vocational schools. For efficient working of a graded system these institutions should provide instruction for workers who are intermediate between the manual and the professional levels. But, since the professional teaching institutions usually enjoy a higher status than the vocational ones, there is a natural tendency for the latter to gradually change their educational objective in an endeavour to attain to the professional status.

A striking example of this tendency is to be found in the United States, where many institutions, which were founded to provide for the needs of the vocational worker, have gradually left that field of work, and now purport to give a professional type of training. Judging from American experiences it appears that the educational system of the country does not benefit as a result of this change in objective. Indeed there are usually two unfortunate results. In the first place the educational system becomes unbalanced, since insufficient facilities remain available for instructing the vocational workers; and secondly the promoted institutions are usually unable to provide a truly professional type of instruction. This latter circumstance is the result of the combined action of several factors.

The first is that although these schools alter their educational objective they seldom change their recruiting policy. Thus their classes are composed chiefly of men who have not had the advantages of a prolonged, general type of secondary education; and without this cultural foundation it is impossible to produce really satisfactory professional men. Then secondly, these schools normally remain wholly technical in scope; thus their students are deprived of the education that comes from frequent, informal contacts with students and staff of a non-technical outlook. And thirdly, these institutions usually endeavour to give a professional education while still retaining a teaching staff that has been brought up in a vocational atmosphere. Indeed in many cases they expect staff members to give a professional type of instruction during the day, and a vocational one at night.

These, and other allied factors, result in the students of these schools failing to obtain a truly professional training and outlook. Consequently they usually tend to view industrial questions as so many purely technical problems rather than as component parts of a general social problem.

In an endeavour to prevent this blurring of educational objec-

tives most industrial countries have introduced some form of co-ordinating control. In some cases all sections of the technical scheme have been placed under the control of a single government department. Normally this organization has been effective in controlling the trade and vocational sections, but it has usually resulted in an undue cramping of the professional division. This is only natural since the chief function of this latter section should be the development of new principles. This cannot be done effectively if either the schedule of studies, or the general organization of the institution, is controlled in the rigid manner that usually characterizes the work of goverment departments.

In the vocational and trade sections the advantages of a central and rigid authority outweigh the disadvantages, for the primary objective of these schools should be to train men in certain established methods of production. They should also deal with the basic principles of science that underlie these methods, but should not be concerned directly with extending this field of knowledge. Their work is controlled chiefly by existing industrial practices; and the stabilizing and standardizing effect of a central governmental control facilitates rather than handicaps their activities.

However under the existing British scheme, with autonomous Universities and government controlled technical and trade schools, there is a definite need for some organization to correlate the activities of the professional and vocational sections of the technical scheme. In this connection the experience of Germany should be of value.

In that land although all grades of technical education are under government control the "Technische Hoch-Schulen" are organized under an authority separate from that which controls the work of the lower grades of technical work, and these former institutions are allowed a considerable degree of academic freedom. The activities of the various sections of the technical education system are correlated through the activities of a non-governmental committee which has been organized by the Verein Deutscher Ingenieure. This committee[1] which has existed since 1908, is representative of "all professional and industrial interests in technical education from the training of workmen to that of directing engineers," and has a very great influence over the work of all grades of technical education. By this means the advantages of consultation and co-operation are obtained without placing any hampering restrictions on the institutions which specialize in the professional type of training. It is to be hoped that this system will be adopted by other industrial countries.

1. S.P.E.E. *Report on Investigation of Engineering Education*, pp. 802, 956.

Selection of Students.—One of the most important problems that confronts any modern State is that of ensuring that its youthful citizens are directed into occupations where their work will be of benefit both to themselves and to the community as a whole. If this problem is not satisfactorily solved it will have very adverse effects on both parties. Thus schemes should be developed to direct each citizen into an occupation which will suit his particular gifts, and which at the same time will be of definite value to the State; the guidance must also be such that useful employment in the chosen field of work will be available for each citizen on the completion of the training.

This problem of guidance involves more than merely selecting a branch of industry or commerce—such as engineering—since each youth should also be advised as to whether he should train for the professional, vocational or manual work section of the selected industry. Consequently, quite apart from the difficulty of predicting the probable future labour demands of the various callings, the problem of student guidance is most involved. Further difficulty results from the fact that at the time of selection many youths have little real knowledge of the nature of the work done in the various trades and professions, while in other cases the youths concerned are too young to exhibit a special aptitude for any particular type of work.

In countries that have adopted a graded system of technical education correct guidance as between the various functional groups is most important, for as one moves from occupations of a trade nature to ones of professional standing both the duration and the difficulty of the training courses gradually increase. At the same time the number of openings for employment decreases at a very high rate. Consequently any youth who enters upon a course of training that is in advance of his natural abilities falls into a most unfortunate position—not only will he probably be unable to complete his chosen course of training, but by the time he discovers his mistake he will usually be too old to transfer successfully to some less difficult training.

In the trade and vocational spheres this problem is not usually one of great difficulty, because the work in each of these is fundamentally practical in its outlook. Thus if an ambitious youth finds that the vocational type of training on which he has entered is too advanced for him, he can usually transfer into the trade section without undue trouble. However in the case of the professional type of training a much more serious problem arises, since youths who fail to complete this training will be probably too old to enter into vocational work. Consequently great care should be taken before any youth is advised to attempt a profes-

sional training since an unfortunate choice at this stage will cause the youth to waste valuable years in a probably vain attempt to graduate from the course. In addition the presence of any considerable number of such students in a professional institution will greatly retard the progress of the really professionally minded students.

At present few students have any opportunity of obtaining worth-while advice on this problem, and ability to pass the matriculation examinations is usually taken as sufficient indication that the youth will be capable of profiting from a professional type of training. From a review of the examination results in certain technical faculties it would appear however that this bulwark is insufficient; thus it will be necessary for the Universities either to modify their matriculation requirements for these faculties *or else to set up efficient schemes of vocational guidance for the* benefit of intending students. Admittedly the existing matriculation requirements of most Universities should succeed in restricting the undergraduate ranks to persons of adequate scholastic attainments; but for success in the technical faculties more than this is required as the students' mental ability must be supplemented by that definite, though rather undefinable, attribute known as aptitude for technical work of a professional character.

Thus the modification that is needed in the entry conditions is not an added emphasis on scholarship, but rather a test of personality and interests. To be of any real value such a test would need to include a personal interview, and would be designed to pick out students with definite technical aptitudes. Further it would select students who would endeavour to think for themselves when placed in new situations—as opposed to ones who would fall back on precedents, formulae and directions—and who would combine an ambition to do something new or distinctive with an ability to accurately observe their surroundings.

Transfer of Students.—Irrespective of what system may be adopted for selecting students for each grade of technical education a certain number of misfits will always be discovered after the training has been in progress for some time. Consequently every graded scheme should make definite provision for the transfer of students.

This problem is of chief importance in relation to transfers from the vocational to the professional grade of training, since the suitability of a youth for the latter type of training is often not noticeable until he reaches a fairly mature age. At the present time the general tendency is to encourage any exceptionally gifted student who may be discovered in a vocational type of training to complete this work before proceeding to a University for a professional

training. In such cases the student is usually granted exemptions from certain of the earlier subjects of the University curriculum. In many cases this policy has produced very excellent graduates; but at the same time the procedure is an illogical way of assisting these students, for it assumes that the essential difference between a professional and a vocational training is contained in the subjects that are grouped in the later years of a University course.

Actually this is far from the truth, for the distinction really arises from two other sources. In the first place it is due partly to the training in general subjects that the student normally begins in his secondary schooling and continues during the earlier years of his University course. Also it is influenced very considerably by the experience in living that the undergraduate obtains through his activities in the general student life of the University.

Therefore it appears that a more satisfactory solution would be obtained if the brilliant misfits of the vocational schools were granted such financial assistance as might be necessary to allow of their immediate transfer to a secondary school of the general type where they would receive an adequate general education as a preliminary to a full University career.

Amongst the other transfer problems that arise in a graded system that of retrogression from a professional to a vocational type of training is the most important; but as this problem has already been mentioned under an earlier heading it is not necessary to do more than re-emphasize the unfortunate position of this class of student. The difficulty in this case is not that of arranging a transfer to the vocational type of training, but of obtaining any suitable openings in industry for men who are probably well above the usual recruiting age for vocational workers. In America an investigation[2] was made recently into this question. This indicated that these misfits had very little chance of being absorbed into the vocational section of industry, and that their best prospects lay in transferring to some activity which did not require a specialized education as a pre-requisite to entry.

Full-time and Part-time Courses.—Throughout the history of technical education there has been a long drawn-out conflict between the advocates of full-time and part-time courses. Even now the policies of industrial nations show no general agreement on this question. England is still the leading advocate of part-time technical education; and with the exception of the Junior Technical Schools and the numerically unimportant Senior Courses the whole of the English scheme is based on this principle. However it should be noted that these part-time activities can now be

2. S.P.E.E. Report on Investigation of Engineering Education.

divided into two distinct sections, according to whether or not the studies are carried out during normal working hours.

Although the great bulk of this technical education still occurs in the student's own time it is significant to note the growing success of the efforts which the educational authorities are now making to popularize the alternative method. Indeed when the historical background of English industry, and the conservative nature of the British temperament are taken into account the progress of this new idea is astounding. Without doubt the adoption of this principle of "time-off, on-pay" to attend technical school classes is a great step forward; indeed it represents almost as great a change of front on the part of employers as would now be involved in the adoption of a full-time, pre-employment scheme of training. Perhaps the future will show that the part-time principle is not quite so firmly rooted in England as has been generally imagined.

In France and the neighbouring Continental countries other than Germany, part-time technical education is not generally favoured. These countries are developing full-time systems which are designed to give technical training to youths before they enter industrial employment. It is however interesting to note that the educational system of Czechoslovakia, which has been developed in its entirety since the European war, makes provision for the extensive use of each of these systems of technical training. This development is most interesting, and is based on the general idea that full-time instruction is required in those industries where the works processes are definitely based on scientific principles, or where goods are produced on mass-production lines. Part-time instruction is accepted as the more suitable method in the craft type industries.

Craft industries are now declining in importance in comparison with mass-production ones. Thus the general position for industrial nations as a group can be summarized in the statement that, while full-time training is the objective towards which most educational bodies are striving, the achievement of this aim is hindered by two main considerations. The first is that existing industrial personnel has grown up in a works atmosphere, and in general is still distrustful of any scheme that removes youths from the works for lengthy periods during their training. The second is that the adoption of any scheme of full-time training imposes an added financial strain on parents.

However the disadvantages of part-time schemes are so pronounced that it is difficult to see how a progressive State can afford to continue this method, except as an auxiliary to a full-time scheme. This applies particularly in the case of part-time courses that are held at night since in these the physical fatigue

of students prevents any adequate mental concentration. In addition the time available under these conditions is quite inadequate, and even in courses which extend over five years it is usually impracticable to include any adequate study of non-vocational subjects. Actually these courses are usually restricted to technical essentials with the result that in later life their students are frequently handicapped by an inadequate knowledge of general subjects. The broken nature of the courses also prevents students from settling down into that calm and reflective attitude that is so necessary if any effective intellectual work is to be accomplished.

A further disadvantage is that the free time of the students is greatly reduced by attendance at evening classes; thus many of these students have insufficient opportunities for recreation. Also if the evening school is not operated in conjunction with some day classes there are the added drawbacks that the buildings are inefficiently utilized, and that teaching is regarded by the school staffs merely as a subsidiary activity.

These latter points can be removed by operating the evening work in conjunction with other full-time activities, but even then the other disadvantages should be sufficient to prevent it from being regarded as a primary method of imparting industrial instruction.

The disadvantages of part-time instruction are further reduced if these classes are held during working hours. Then the problems associated with student fatigue are greatly lessened; and so long as the total attendance is large enough the staff and buildings can be utilized for a reasonable period in each week. But the scheme is still subject to the other disadvantages that have been mentioned. Also the effectiveness of part-time day instruction is often adversely affected by the passive resistance offered by officials such as works-foremen, whose production schedules are disorganized when youths are allowed time-off during the normal working hours. However this trouble is probably a passing one which will gradually disappear as the older foremen are replaced by ones who have had the benefits of a school type of training.

Even under the most favourable conditions any part-time scheme of instruction will be educationally inferior to the corresponding full-time system, and so the latter organization is preferable for all major fields of work. But the part-time method is especially suited for the instruction of ambitious men who cannot afford to maintain themselves during a full-time course, and so it will always be a valuable auxiliary to full-time schemes.

The full-time principle is generally recognized as the superior one, but its final and complete adoption will be a rather distant event, since it cannot finally triumph until two previously

mentioned preliminary conditions have been fulfilled. In the first place the practical man must be convinced that the school is now able to provide a more satisfactory industrial training than can be obtained in the works; and secondly some scheme must be developed to compensate parents for the loss of income and the expenses in which they would be involved by the adoption of a full-time type of industrial schooling.

As these conditions are gradually fulfilled the full-time type of technical education will become the usual procedure for all sections of industrial training, instead of being confined to the professional level. However, these changes will take many years to bring about, and for the immediate future the activities of educational authorities in English-speaking lands will probably continue to be directed towards popularizing the part-time day class as the basic method of training for the vocational and trade sections of industrial work.

Mono and Polytechnic Units.—A further problem that frequently confronts a central administration is that of deciding whether its trade and vocational type schools should be organized as monotechnic or as polytechnic units. This problem seldom arises at the professional level of instruction since this work is usually carried out at a University, and these institutions are necessarily polytechnic in outlook. Admittedly there are a few exceptions to this statement; but the monotechnic institution of professional status is a rare occurrence. The chief example of its adoption is found in Germany.

In the trade and vocational sections of education the position is entirely different, and a great deal of the success of European technical education is normally attributed to the close relations between school and industry, which are made feasible by the monotechnic organization of these schools.

This is especially evident in the case of the textile and coal-mining schools, while a further example is supplied by the monotechnic type of works' school which has played such a large part in training artisans for the rapidly growing industries of Russia.

In view of such facts as these the advisability of a wider adoption of the monotechnic organization is frequently urged upon educational authorities. In this connection it is pointed out that under this scheme each industry has to deal with only one scholastic organization instead of with many small departments as is the case in a polytechnic organization. Consequently the solution of such problems as those of maintaining uniform standards, of integrating industrial developments into the school curriculum, of stimulating the interest of students in works processes, and of regulating the number of students to correspond with the absorptive capacity of the industry, is greatly simplified. Further with

a monotechnic organization a very considerable saving can usually be made in the cost of equipping the schools with the necessary machines; also the teaching staff for each industry is concentrated into a single unit so that its oversight is facilitated and the status of the positions can be adequately graded in importance and remuneration.

But as a counterbalance to these advantages it must be realized that a monotechnic school can only be successful if it is located in a sufficiently homogeneous and sympathetic industrial environment. Indeed in order to obtain really satisfactory results it is usually necessary for the school to be located in a district that is devoted practically entirely to the one type of industry. If this condition can be fulfilled then the success of a monotechnic school of the trade type is practically assured. For schools of the vocational level the problem is made more difficult by the fact that though the industry may be concentrated round the school yet the pupils may be drawn from a much larger area. This is of importance since the transport and accommodation of students from remote districts will result in a considerable increase in the costs that fall on the parents. In an endeavour to overcome this trouble the French Government makes a considerable contribution towards the total costs of maintaining students at its chief vocational schools. These are organized as residential units and are located in the chief industrial centres.

In addition to its dependence on environment the monotechnic school suffers from certain other severe drawbacks. In the first place the whole usefulness of a school may suddenly disappear as a result of a change in the fortunes of the corresponding industry. In such cases reorganization will be a very difficult task since both staff and students of a monotechnic school quickly become imbued with its specialist outlook and traditions. Indeed even if such a calamity does not occur the educational usefulness of these schools will decrease as time goes on, since the staffs tend to lose touch with problems that lie outside of their immediate sphere of interest. Thus the outlook of the students becomes narrower than that of youths from a polytechnic institution.

The position may be summarized by stating that under suitable conditions the monotechnic organization tends to increase the effectiveness of the school as a mere training ground for a given branch of industry; but at the same time it fails to impart a sufficiently broad outlook to its staff and students. Therefore, while this mode of organization may be thoroughly justified as a means of giving specialized trade training after the completion of an adequate general education, the monotechnic school is not the ideal choice for vocational or professional training since a relatively broad training is desirable throughout the whole of these courses.

CHAPTER X

PROBLEMS OF TECHNICAL EDUCATION
(Continued)

Examinations and Certificates

WITH the decreasing importance of the works as the training ground for industry it is becoming increasingly necessary to maintain an adequate system of terminal certificates which will indicate the general competence of the holders. Frequently the first contact between an employer and his recruits occurs when the latter apply for employment, and so the employer must be guided very considerably by the credentials of the applicant. This is especially so in the case of professional appointments, since these workers are drawn from a wider geographical area than are the members of other sections.

Thus an adequate scheme of certification of students can play a very important part in industrial life, but for real success it must comply with certain requirements. For example the certificates must be recognized by a wide body of employers; and the standard of award must remain at a similar level all over the country. But at the same time the examination system underlying the award of the certificates must be such that the initiative of individual schools and teachers will be maintained. Further the whole scheme must be so organized that it will encourage the industrial world to take an active interest in the work of the schools.

With trade workers a close tie usually exists between the local school and the various works so that employers tend to be guided more by the recommendations of masters whom they know personally than by a certificate of competence which has been issued on the authority of any central body. But even in this class of work some applicants for employment may have been trained in towns other than the one in which they wish to work. Consequently the issue of a nationally recognized certificate has become necessary to mark the successful completion of the course of training. Actually the majority of industrial States have already adopted this idea, but the mode of awarding the certificate varies fairly widely.

In France the examination for the "certificat d'aptitude" is usually conducted at each school by a panel of examiners that is representative of the employers and the employees of the appropriate trade, the official bodies responsible for conducting the school, and the school staff. In many cases this examination which is

largely of a practical nature can be attended by any interested person. In Belgium and Holland each school issues its own certificates, the right of entry to the final examination being restricted to students who have satisfactory school records. The actual examination in each subject is carried out by a jury composed of representatives of the corresponding employers and workers. This committee is responsible for setting and marking all examinations, whether written or practical, since it is felt that this close co-operation between school and industry ensures that the school instruction is kept up to date, and that the certificates are generally recognized by the local employers.

In England the issue of certificates to trade workers has not been very widespread, since English schools have not as yet taken such a prominent part in training trade workers as have Continental ones. In cases where the system has been adopted the general tendency has been to base the examinations on the requirements of a central examining body rather than on those of a jury drawn from the local industries. Admittedly this reduces the closeness of contact between school and industry, and so lessens the appeal of the certificates to many employers; but it also tends to develop a more progressive attitude towards new processes than would otherwise be the case. In England the City and Guilds Institute has been the chief of these examining bodies; and, as its examinations are set and assessed on the advice of national committees which represent the respective trades and schools, the contact with industry is maintained on a national rather than a local basis.

In the vocational sphere of training England has tried several methods of issuing certificates to youths who have successfully completed a course of instruction.

Originally the award was controlled by a central authority, and was based on the results of external examinations which were set and corrected by the central body. This led to troubles arising from standardized curriculums; and in order to introduce greater flexibility into the courses these examinations were later replaced by a system of school inspection in conjunction with internal examinations. Under this scheme each school conducted its own examinations and issued certificates which were endorsed by the central body, provided that the school concerned had received a satisfactory report from the external inspectors.

Experience showed, however, that under this system it was impossible to maintain a sufficiently uniform graduation standard over the whole country, and this led recently to the widespread adoption of a system which was designed to combine the merits of the earlier ones.

sionnelles) should be of value since these are typical of the best Continental practice.

This group of schools employs about 4,500 staff members who are recruited from four main sources—namely (i) graduates of science or technology courses, or in some cases, final year undergraduates, (ii) technicians in industrial employment, (iii) trained teachers from the elementary and middle schools, and (iv) trade workers. Special training schemes are maintained for the further instruction of each class of recruit prior to their admission to the actual teaching staffs. For example those who hold University qualifications spend the greater part of a year in practising the art of teaching; recruits from the technician class are required to attend part-time classes in general educational subjects for one year, and after this spend a further year of part-time instruction in the art of teaching. Also those teachers from the general schools who wish to teach general subjects in the Trade Schools are encouraged to attend technical courses at these schools as pupils, so that they may realize the needs of technical education and evolve plans for correlating their general subjects with the technical work of the students.

In addition to providing these training schemes for teachers of general and of technical subjects great care is taken in choosing the full-time teachers of trade subjects. These men are selected from applicants who, after obtaining the diploma of an école professionnelle, have had at least five years of satisfactory trade experience. These applicants submit samples of their drawings and manual work, and after passing an oral examination on trade methods each successful recruit spends one year as the assistant of a qualified trade teacher before he is allowed to take independent charge of a class.

Consequently the work of the Belgian trade and vocational teachers is of an unusually high order, and this is probably a distinct factor in the success of the export trades of this closely populated country. It must however be realized that the effectiveness of these Belgian staffing arrangements is due largely to the widespread adoption of full-time technical instruction. This enables men to regard teaching as a life work, and not merely as a spare-time occupation as is necessarily the case in lands where part-time schemes are the general rule. Probably England furnishes the greatest example of the part-time system of technical education, and it is interesting to note that the English scheme makes little or no provision for the pre-appointment training of its technical teachers. Recently however a series of ten-day residential classes has been organized during the summer vacations to provide facilities for the further training of teachers in engineer-

ing, building, textile and commercial subjects, and these have met with considerable success. Even so they must be regarded as a very unsatisfactory substitute for a universal scheme of pre-appointment training and it is hard to see how any scheme of technical education can really succeed unless the great majority of its teaching staff is thoroughly trained in the art of instruction as well as being well informed on technical questions.

In the professional section of technical education the problems associated with recruiting an effective body of teachers and of maintaining a steady development of their professional outlook and knowledge have not as yet been faced in any very thorough manner. Recently the whole position has become more acute as a result of the increased competition that has arisen between industry and the Universities for the services of suitable recruits. Consequently it is probable that these problems will be more adequately considered in the near future.

In the past the higher teaching positions in the technical sections of the Universities have been filled without any great difficulty since the Universities have been the unchallenged leaders in scientific and industrial research. Consequently men who had a desire to contribute towards the advancement of technical research accepted University positions. But in recent years much of the initiative in research has passed from the Universities to the large manufacturing companies. These now realize the importance of research both as a weapon of offence and of defence in trade relations, and are therefore devoting very large sums to build up adequate research facilities.

Thus in many cases industry now offers the brilliant theoretical worker not only a better salary prospect, but also better facilities for carrying out research work, than are available in the Universities, and so there is a decreasing tendency for such men to devote their lives to University work. Indeed many educational leaders in America and England are convinced that it will be necessary to adopt a modified method of recruiting men for the senior technical positions in the Universities; and certain of them are advocating the establishment of special training courses for persons already on University staffs so that a larger proportion of the senior positions may be filled by the promotion of junior members.

This question was considered recently by an investigating committee of the Society for the Promotion of Engineering Education. This report pointed out that a continuance of the present state of affairs would injure industry as well as the Universities, and that a solution could only be effected by establishing some form of co-operation between these bodies. It therefore suggested that the Universities should definitely recruit promising young graduates

for a teaching career. After a short period of teaching work these men would be transferred to the works of the co-operating industries for special training courses which would be designed to bring the trainees into intimate relations with the leading engineers and officials of the co-operating company. At the conclusion of this works experience the trainees would spend a further period at selected Universities to carry out individual research work and to attend post-graduate courses, and from this work they would be gradually transferred to teaching positions of moderate responsibility.

By these means it is hoped to build up University staffs with men whose training will be sufficiently wide and advanced to permit of their being promoted to professorial positions after a few additional years of teaching and research experience. Up to the present these proposals have not been developed into any widespread plan; but it is interesting to note that leading industrial executives both in the U.S.A. and in England have expressed themselves as being in full agreement with them.

However it must be realized that while such a scheme would assist greatly in maintaining a supply of men suitable for advanced University positions it would not of itself be effective in maintaining the necessary mental fertility of the teaching body. This can be done only by encouraging staff members to engage in appropriate post-appointment activities.

In many branches of technical work research in some aspect of pure science is now regarded as the only acceptable way of attaining this end; but it is very desirable that this view should be broadened, for similar results can be obtained by other methods. Admittedly pure research has proved its usefulness in this connection; but it cannot be denied that in at least certain of the technical faculties a similar result can be achieved by encouraging staff members to spend extended periods in the employ of progressive companies, by organizing staff exchanges between suitable Universities, or by allowing staff members facilities for investigating changes which may have occurred in the educational methods of other lands. Further, at the present time the professional standing of many industrial callings is very poorly established, and in these cases it may be necessary for the non-teaching activities of University staff members to be directed towards establishing and building up adequate professional and scientific organizations which would generally stimulate the life of the corresponding professions.

But if members of a University staff are to take an effective part in such non-teaching activities it is essential that their time should not be too fully occupied by formal duties. Also the general atmosphere of their institution must be such as will encour-

age staff members to engage in these additional activities. Thus it is essential that the teaching loads should not be excessive, that leave systems should be well established and adequately financed, and that the institution should encourage staff interchanges both with other Universities and also with industrial companies.

Contacts with Industry.—In order to maintain the effectiveness of the various types of school as training grounds for industry it is essential that there should be close co-operation between these two sections. Otherwise the recruiting plans of industry may not be modified to fit in with changes in the educational system, while the schools may fall out of touch with developments in industrial procedure. Such co-operation is also desirable to strengthen the position of the schools as the training ground for technical workers. Even now a large proportion of industry is still unconvinced that industrial recruits should receive their training in the school rather than in the works; and one effective way of overcoming this prejudice is to maintain the closest possible contact between the schools and industry.

The actual steps that should be taken to achieve this will vary according to the type of school that is under consideration; but they will all fall under one or two main headings according to whether they bring industry to the school or the school to industry. In the first place arrangements may be made to educate industrial employers and employees in the advantages of the school type of training by placing them in positions where they will have a direct control over the standards required for graduation from the course of training. Thus in European countries it is customary for the final examinations in trade subjects to be conducted by juries composed of employers and foremen drawn from the appropriate industry; while in England instruction in these subjects is carried out chiefly on a part-time basis by men who are actively employed in the particular trade processes for the greater part of the time.

This active co-operation of industrial personnel in maintaining school standards is important, for it increases the confidence of the general body of industry in the adequacy of the school training. Thus it improves the employment prospects of the trainees.

This type of co-ordination is more easily arranged in trade subjects than in the more scientific types of training; and in the vocational field the only really satisfactory scheme of co-operation which has been put into practice in England is that of the National Certificates. Under this scheme, which has been described fully in an earlier section, the standard of training in vocational institutions is vouched for by the corresponding national professional societies, such as the Institution of Electrical

Engineers, and the experience of the last few years shows that this indirect link with industry is a most useful one.

In the professional field of training a rather similar example of an indirect link between the educational system and industry is to be found in a scheme of supervision which is now being introduced in the United States. Here the various Institutions of Engineers have set up a central co-ordinating committee which is endeavouring to correlate the standards of engineering education in the Universities of that country.

Before passing on to the second group of methods it is desirable to mention the practice of appointing prominent industrialists as members of the controlling body of an educational institution, or as members of special advisory committees. Under favourable local conditions this procedure may provide quite a satisfactory link between the school and industry; but in many cases it results in serious complications as these appointees sometimes endeavour to unduly influence the whole educational procedure of the institution instead of acting merely as links between the school and industry.

Although examples of the second group of co-operative activities —namely those in which the essential motion is from the school to industry—are to be found in all types of industrial education they are of greatest importance in the professional level of training. Consequently it is proposed to defer a full consideration of this problem to that section of this work which deals with the professional training for the engineering industry, and the present discussion will be confined to outlining the chief fields of co-operative activity that come under this second grouping.

Probably the most important of these methods of co-operation are those which involve a regular interchange of professional staff members between the industry and some particular University. In other cases very satisfactory results can be obtained by the rather simpler expedient of assisting members of the University staff to obtain vacation appointments with progressive firms. Then again considerable benefit can accrue to both parties through the establishment of schemes of co-operative research which place the facilities of an industrial undertaking at the disposal of the University research worker. By these means results of considerable value to the industry are frequently obtained; the outlooks of both sets of workers are broadened by their mutual contacts; the University is kept in touch with current industrial practices; and the prestige of the teaching institutions is enhanced in the eyes of the industry.

Finally valuable co-operation can be effected by establishing courses of lectures which are designed to meet the needs of practising members of the industry.

PART III

EDUCATION FOR THE ENGINEERING PROFESSION

CHAPTER XI

PROFESSIONAL TRAINING FOR ENGINEERING

AT this point we leave the wide field of industrial education and concentrate on that particular section which prepares men for the professional level of engineering work. The primary reason for the selection of this particular aspect of educational activity is that this profession, which is now beginning to play a very important part in the general life of the modern state, has changed from an empirical to a scientific basis under modern conditions. Consequently the problems which now confront this section of the educational system should be representative of those which will have to be solved in other educational fields as the scientific outlook gains ground in the corresponding industries.

The Engineer and the Community.—The importance of the engineer as a member of the community has been growing over a long period, but it is only in recent years that the rate of growth has been greatly accelerated. Originally engineering activities were merely incidental, being performed by individual citizens whenever the need for such services became pressing. As time passed these activities gradually became the prerogative of specially trained men, and during the last two hundred years this specialist organization has been greatly strengthened by two main factors.

In the first place this period has witnessed a great increase in the complexity and social importance of machinery; and secondly, mankind has been forced during this period to organize most of its essential services on a community basis.

Thus the social organization is now of such a nature that the continued employment of those citizens who are known as the industrial workers is absolutely dependent on the activities and skill of the professional engineer—indeed even the personal comfort of the former group is largely conditioned by the attitude that the engineer adopts towards certain social problems. Actually this dependence of the "worker" on the skilled "professional man" is now tending to spread into the agricultural realm, for in many countries primary activities are now largely influenced by mechanical devices.

Thus the engineer plays an essential part in directing the working life of the majority of the community; in addition social services such as transport and water supply, which the average citizen commonly takes for granted, could not be maintained without the services of a suitably trained body of engineers.

Admittedly these professionally trained men are frequently not free agents, since in many cases they are under the control of some financially powerful authority; but even so their work is of such a nature that their employers are generally compelled to place great reliance on any advice which they may give. In this way their attitude towards social problems becomes a matter of great importance.

In the past the engineer has been accustomed to report upon a proposed scheme from the viewpoints of its technical soundness, of its costs and financial returns, and of its efficiency in obtaining the result which is desired by the engineer's employer; in most cases no effort has been made to examine the project critically in order to determine its effects on the life of the community. At present this outlook is the natural one, for as yet the community has not demanded that the social aspects of these problems should be exhaustively examined before any development is undertaken. Recently however there have been indications of an impending change in policy, and it is probable that the engineers of the future will have to take a much broader view of their responsibilities than have those of past generations.

The Historical Background of Engineering Education.—In England education for the professional level of engineering began at a relatively late period in the country's industrial development. This was due chiefly to the fact that the initial success of British industry was based on the activities of men who had risen from the rank-and-file of industry as a result of their own genius, and not because of the existence of educational facilities. These pioneers[1] were essentially inspired, practical men. As a result of their marvellous successes English public opinion steadfastly upheld the superiority of practical as opposed to theoretical methods of training men for industrial pursuits.

The fundamental unsoundness of this outlook was realized fairly early in the 19th century by certain advanced thinkers, but their efforts to establish a truly professional type of training in engineering were frustrated by the fact that during most of that century the English Universities strenuously opposed the introduction of scientific studies. Consequently it has been only during relatively recent years that any effective form of education has been introduced for the benefit of engineering students—indeed its introduction dates only from the close of the century, when other industrial countries began to challenge England's early supremacy in the export field.

1. Newcomen (an ironmonger); Brindley (a millwright); Arkwright (a barber); Crompton and Hargreaves (weavers); Smeaton and Watt (instrument makers); Telford (a stone mason); Stevenson (a fireman).

As a contrast it is interesting to note that as early as 1747 France established a professional type of education for the benefit of men who intended to enter the technical sections of her public service. Corresponding facilities for those in training for private employment followed soon afterwards. This early establishment of a professional type of training was undoubtedly one of the chief factors that afterwards enabled France to make up her initial leeway in industrial affairs; but as has been noted elsewhere she later forfeited this advantage as a result of poor administration.

A further factor of importance in the development of French industry was that her general educational facilities were relatively well advanced before her industries began to expand rapidly; whereas in England practically all the educational development occurred after the industrial revolution. As a result of this historical background French public opinion has been more enthusiastic in its support of the professional type of engineering education than has that of England.

In Germany this branch of education was initially handicapped by the fact that the classically-minded Universities refused to be associated with it. Thus an independent system of engineering education had to be established. These institutions gradually raised their standards until they finally achieved University rank, and during recent times they have received great support both from the government and from the general public. This has been due largely to the fact that the research activities of the "technische hochschulen" played an essential part in the phenomenal development of German industry during the 20th century. These Universities have now become the heart of the German industrial system, and the benefits accruing from their activities have been so pronounced that the public has become their consistent champion.

In the United States inherited traditions and the field nature of the early engineering activities in a vast new continent favoured the development of a practical type of engineering education. Indeed in the early days an ability to handle men was of vastly greater importance than a knowledge of the methods of applying mathematics or science to the solution of practical problems. Thus public opinion initially favoured education along the traditional British lines.

This attitude was challenged by some of the early American engineering schools, such as West Point and Rensselaer, which had come under the influence of the French tradition. However most practising engineers upheld the British tradition of training through practical experience, and no major alteration in outlook occurred till the electrical and chemical industries began to develop during the latter part of the 19th century. This caused a con-

siderable number of scientists to join the staffs of the engineering departments of the leading Universities, and this led to the gradual acceptance of the theoretical approach as the basis of an engineering education.

At present the better Universities, and also the various Institutions of Engineers, are paying increased attention to the theoretical type of engineering training; and the present educational position is somewhat intermediate between that of England and that of Continental countries.

The Objectives of a Professional Training.—If the graduates of training schemes are to be active and useful members of the engineering profession certain requirements must be fulfilled. The primary one is that these men must be adequately skilled in the scientific techniques associated with the control of forces and materials; secondly they must be experienced in the accumulated practical knowledge of the profession; thirdly they must be skilled in the art of organizing human effort; fourthly they must be able to make a full contribution to the general life of the society of which they form a part; fifthly they must be capable of apprizing the benefits and disadvantages which will fall upon a community as a result of the adoption of a particular engineering procedure; and finally, they must be able to apply the experiences which they derive from the foregoing activities to the development of new lines of thought and action in the sphere of engineering.

Thus education for this group of professional men must do much more than merely teach technical subject-matter. It must also build up in students an attitude of stewardship towards the community, while simultaneously developing their powers of constructive thought, so that they will act as creators of engineering technique and not merely as imitators of the past. Consequently the primary objective of this branch of education should be to develop the student's mind, and his ability to use it for constructive thought, rather than to fill it with vast amounts of detailed factual knowledge relating to the practice of the profession.

This is now being increasingly realized by educationalists, and in this connection the published statements of Dean Doherty of Yale University are of great interest. In his article[1] the fundamental objectives of an engineering education are summarized as follows:—

(a) The course of studies should develop the habit of scientific thought, and assist students to discriminate between

1. *General Electric Review*, Vol. 38, p. 168.

problems which can be expressed quantitatively and those that cannot.

(b) It should develop one's ability to organize one's thoughts, and to express these clearly and logically.

(c) It should impart an intimate knowledge of the sciences that are fundamental to the particular branch of engineering.

(d) The course should give students an adequate historical perspective of social, economic and engineering developments which have occurred in the community; it should develop a cultural balance in its students.

(e) The course should produce students who will be capable of co-operating effectively in group activities of a social as well as of a technical character.

Naturally the graduates of a scheme of education which was restricted solely to these objectives could not be regarded immediately upon graduation as fully-trained engineers, for the whole emphasis of such a course would be on education rather than on engineering. But a course of this nature would produce minds capable of appreciating and of investigating new situations, and its graduates would tend to continue their mental development throughout their working lives. Graduates of this character would quickly develop into satisfactory professional men provided that they were given adequate post-graduate facilities for studying the practical procedures of the profession.

Thus the complete training of a professional engineer is a prolonged procedure and must be built up from several component parts. The first of these, which extends up to an age of about eighteen years, is devoted to general education of a non-vocational character. This is followed by a three or four-year course of undergraduate study at a University. In certain cases this may lead on to a period of post-graduate study or research. Normally the formal theoretical section of the training concludes at one or other of these latter stages, and then the graduate passes on into that long-continuing educational process which is known as professional life. Usually the early years of this life are devoted to a rather intensive study of practical procedures, since no one can be recognized as a fully qualified member of the profession until he has obtained this experience; but for lasting professional success these practical studies must be supplemented by the continued study of general theoretical subjects.

At present it is generally agreed that an engineering training should follow along these general lines, but considerable differences of opinion exist amongst English-speaking engineers as to

the best detailed manner of utilizing the 18 to 24-year period. Some hold that general education should take precedence over purely technical instruction during this stage of the training; others maintain that the practical aspects of engineering must be kept prominently before students throughout the whole period. However with the gradually increasing importance of scientific methods as the common link between a number of highly specialized branches of engineering the former view is gaining ground, so that the modern tendency favours the development of undergraduate courses in which the major emphasis is on education rather than on technical instruction.

This is a relatively recent development, for in earlier years the Universities tended to develop their undergraduate courses along rather specialized technical lines, so that on graduation students would be highly skilled in the practical techniques, as well as in the theory, of some chosen field of engineering work. The retreat from this position is due chiefly to the fact that engineering has recently grown so much, both in extent and in specialization, that no University can provide more than a fraction of the specialized courses that are demanded by industry. With the rapid growth of specialized knowledge in each small section the existing undergraduate courses became so terribly overloaded with subject matter that many engineers advocated an increase in the duration of the courses.

Fortunately it was realized in time that, since specialized knowledge in any individual subject will always continue to increase, such an extension could not provide a lasting solution to the problem. Therefore an endeavour is being made to solve this problem by reserving the undergraduate period for training of a truly basic nature, while any specialized work that may be considered necessary is postponed to the post-graduate period.

By adopting this policy the position of the Universities can be greatly improved, since the whole undergraduate period can then be used to develop the minds of the students and to teach them how to think for themselves when faced by unusual conditions. Under these conditions the objective of the undergraduate courses is no longer the production of fully qualified engineers, but rather the maintenance of a supply of graduates who have learned how *to become* engineers. Consequently this period is devoted almost exclusively to the study of such basic subjects as the sciences, mathematics and economics; to practice in applying the principles and modes of thought of these subjects to typical engineering problems; and to training in the art of playing a full part in the life of the community. In such a programme there is little scope for any specialized activities, but nevertheless the work

of the undergraduate period can be so oriented that it will form a satisfactory foundation for the specialized activities of later periods.

In this type of organization the chief function of the post-graduate stage is to train the mind in applying the scientific principles and methods of the undergraduate subjects to the solution of rather advanced engineering problems. In these courses any one student will study problems drawn from a fairly narrow field of engineering work, and so in a sense the post-graduate period is one of specialized activities. Such an arrangement is necessary for two reasons. In the first place these courses are of relatively short duration, and there is not sufficient time for each graduate to cover a wide field of work; secondly, the post-graduate period must be regarded to some extent at least as an introduction to actual engineering employment. Consequently it is often convenient to utilize these courses as a means of introducing graduates to the nature of specialized work. At the same time they should not be regarded primarily as a means of training men as expert practitioners in the specialized fields. Therefore, although the subject matter of these courses may of necessity have to be rather specialized, it is essential that the methods of attack and the modes of thought involved in the work should always be most general in character.

The chief advantage of subdividing the 18-24 year period into an undergraduate and a post-graduate section of the above characteristics is that this allows the University to concentrate on educating its students, instead of merely filling them with technical information. In the second place it allows students opportunities for general studies, for individual thought and reading, and for the establishment of cultural contacts with other students and with staff members. Consequently as graduates they should be capable of taking a useful part in the general life of the community, and should be able to adapt themselves easily to changes in working conditions.

From the point of view of engineering as a whole this organization has the great advantages that it emphasizes the essential unity of all branches of the profession, and that it impresses this fact on students during their most impressionable years.

CHAPTER XII

THE UNDERGRADUATE SYLLABUS

Dual Objectives

ORIGINALLY it was believed that a single level of undergraduate instruction would be sufficient to meet the needs of all men preparing for the professional level of engineering work; but it is now evident that a dual objective must be adopted in this section of the training to meet the needs of general practitioners on the one hand and those of engineering leaders on the other. Actually these two types of workers will finally be engaged on related activities; but, whereas the chief function of the general practitioners will be to carry out usual engineering practices either under direction or else in accordance with established practice, the engineering leaders will be concerned primarily with establishing new lines of thought and activity in the practice, theory and administration of engineering work. In view of this wide divergence of function it is desirable that the general training scheme should be differentiated so as to make separate provision for the two types.

Both types must be given an interest in their profession and in the community in general; both must have a knowledge of the basic sciences. But in the case of the leaders the work should be designed so as to lay considerable emphasis on such intangible qualities as initiative, imagination, personality and resourcefulness. The chief objective of these courses should be to develop graduates who will be tenacious of purpose, and who will have the ability to think soundly in a wide variety of fields relating to engineering work. Thus graduates should be capable of developing new ideas —not merely of solving standardized technical problems.

The general practitioner, on the other hand, will be engaged chiefly on tests and investigations of a relatively standardized nature, in the preparation of reports on engineering projects, and in the solution of technical problems which do not involve new or original theoretical work. Consequently his undergraduate training need not be so profound as that of the leaders, and may have a somewhat more practical emphasis.

But irrespective of whether a course is designed for the instruction of general practitioners or of leaders its subject matter can be divided into three main sections. These can be described as the science and technology, the economic, and the general cultural stems of engineering education.

Training in Science and Technology.—While it is impossible to introduce a scientific type of training unless a sufficient body of well-established scientific data and methods is utilized in the practice of the corresponding industry it is necessary to remember that the Universities should be the protagonists of the scientific method. Consequently it may often be necessary for them to press on towards the adoption of a fully scientific mode of instruction at a rate which may not at first sight appear to be justified by the existing industrial practices. This is especially so during that transition stage when a considerable body of proved scientific data is available, but has not been generally accepted by the industry. Under these circumstances the Universities should remember their function as educational leaders, and give a strong lead in favour of the scientific approach by formulating the corresponding courses of professional training along theoretical rather than empirical lines.

At present there is a divergence of opinion as to the extent to which this scientific approach should be utilized in engineering education. The general position now appears to be that while this approach is very strongly rooted in the electrical, chemical and metallurgical branches, it has a rather less secure foothold in the mechanical and civil branches. To some extent this is due to the fact that the basic theoretical knowledge is more generally available for those branches which fall into the first group; but the position is also influenced by the historical backgrounds of the two groups.

Since very early days the general atmosphere in the electrical-chemical group has been predominantly theoretical and scientific, for these branches of engineering were developed direct from established sciences. In the other group the industries had existed on a practical basis for many years before any serious attempt was made to develop a satisfactory theoretical basis; thus these branches have developed in a predominantly practical atmosphere. At present the scientific outlook is undoubtedly gaining ground in this second group; but its progress is retarded by such factors as the conservative attitude of the average employer, and the rather blurred outlook of some institutions that train recruits for professional openings. However it is certain that the scientific outlook will soon be universally adopted as the basis of a professional training in engineering.

If this training is to be of real value to engineering students it is essential that it should not only provide them with scientific information, but that it should also give them a scientific outlook and a full appreciation of the scientific method of attack on problems requiring investigation. The latter of these two aspects is

the more important, especially in the case of students who are being prepared for professional leadership; but in many cases the undue size of the lecture groups in science subjects, the lack of personal contact between students and staff, and the overcrowded curriculum of engineering courses cause a reversal of this desirable emphasis.

When this occurs the usefulness of the scientific work is greatly reduced, and students usually fail to realize the importance of the scientific method as compared with that of mere scientific data. Unfortunately this tendency is further accentuated by the fact that, while most engineering students can see for themselves that the scientific data will have a direct bearing on their later work, they frequently fail to realize the importance of the scientific method as an engineering tool.

In mathematical work another problem is encountered. Here the chief trouble from an engineering point of view is that the instruction usually lays such emphasis on the methods of mathematics—as opposed to their application to engineering problems—that many students fail to connect these studies with their engineering training. Indeed they regard this work merely as something that must be completed before they are allowed to begin their "real" engineering studies; consequently their interest in mathematics is a forced one, and they fail to realize the value of this subject as a tool in engineering practice.

In some institutions this tendency is further accentuated by the fact that the technical subjects of the later parts of the engineering courses place their major emphasis on practical details rather than on the use of mathematics as an engineering tool. In such cases a method of obtaining at least a partial cure is obvious, but any attempt to rectify the position along these lines would meet with considerable opposition from all those directly concerned.

If the maximum benefit is to be obtained from any programme of scientific and mathematical studies it is essential that this should be supplemented by work which will allow students an opportunity of applying the methods of these earlier studies to the solution of engineering problems of a general nature. Consequently in the later years of the engineering courses the scientific stem should include a certain number of technical subjects; but unless students are taught to approach the subject matter of these courses in an orderly and logical manner this work will lose most of its possible value. In work of this nature it is essential that students should first pick out the basic scientific principle or principles that underlie the given problem. Secondly they must determine whether this principle is directly applicable to the case or whether certain supplementary assumptions or limiting conditions

must be taken into account. Thirdly they must express the whole problem mathematically and endeavour to obtain its solution. Then if the problem is soluble they must be prepared to interpret and criticise the results of the mathematical analysis in the light of the assumptions that have been made in the earlier stages of the work.

In this way students will not only convince themselves of the fundamental importance of scientific and mathematical methods, but they will also develop an ability to judge whether a given problem can be solved by these methods. In addition they will be forced to realize the importance of simplifying assumptions as factors which control the limits of accuracy and the range of application of their theoretical results.

General problem-work of this nature develops the engineering interests of students, but to facilitate the ultimate change-over from the academic to the practical atmosphere it is desirable that it should be supplemented by a certain amount of rather specialized work of a definitely technical character. Usually this need is catered for by laboratory classes and elementary design work; but, while work of this nature is of value in preparing students for the practical side of an engineering life, it is important that it should not be allowed to crowd out the more fundamental work of the course. Care must be taken to ensure that these technical subjects do not lay undue emphasis on mere empirical data, nor on the details of works processes, for once this factual type of work becomes established in a course there is grave danger that the training will become vocational rather than professional in outlook.

Training in Economics.—Even at the present time members of the engineering profession are frequently called upon for opinions on problems which involve economic as well as technical considerations. As the importance of this type of work is continually increasing it is most desirable that at some time during their training all engineers should make a study of the theories which underlie the economic and social sciences. In the past there has been a tendency to postpone this type of work until the post-graduate period, but on account of its rapidly increasing importance to all engineers it now seems necessary for these studies to be included with the other basic sciences in the undergraduate period. A further reason for such a step is furnished by the fact that a man's permanent attitude towards social problems is determined chiefly by the opinions which he forms during the first twenty years of his life. At a later age it is very difficult to approach such questions with an open mind. Therefore it is important that he

should study at least the basic principles of economic and social science while his outlook is still flexible.

Unfortunately many Universities have not yet realized the ultimate importance of this type of study, and in English-speaking countries other than America it is unusual for general economic subjects to be included in the undergraduate engineering syllabuses. Even in cases where these studies are required it will often be found that students regard them merely as isolated courses rather than as integral parts of the engineering work, and so fail to realize their importance as tools which they will use in their professional life. Thus the problem of securing effective study of these general economic subjects is very similar to that already mentioned in connection with the mathematical work. It would appear that the only real solution lies in arranging the content of the technical subjects of the final years of the course in such a way that students will then be forced to apply the knowledge which they should have gained from their economic studies of the earlier years. If this is done students will quickly realize the advisability of treating these earlier subjects as vital parts of their engineering education.

In addition to knowledge of this basic nature it is necessary for the practising engineer to be skilled in those more specialized aspects of economics which are of importance in determining the relative economy of various engineering procedures. He must also have a reasonable knowledge of business and administrative methods, for these factors have a very direct bearing on the financial stability of every engineering organization.

The importance of this latter class of knowledge is more apparent to the average engineer than is that of the basic economic studies; consequently during recent years the engineering profession has exerted considerable pressure on the Universities in an endeavour to increase the emphasis given in the undergraduate courses to this specialized work. However with the exception of the 'administrative courses' of certain American Universities (which are dealt with in a later section) very little has been done to meet the demand.

This is due to two main factors. The first is that most existing engineering courses are already so overcrowded that there is no possibility of introducing any additional work unless the whole course is drastically revised; secondly, even if the time were available the specialist nature of the proposed studies would render them unsuitable for inclusion in an undergraduate course. Admittedly this type of knowledge is of great value to many engineers, but at a time when specialized technical training is being restricted to the post-graduate period there is little justifica-

tion for adopting an inconsistent procedure in the case of specialized economic training.

Further it must be remembered that most engineers do not pass directly from the University into positions which require this specialized knowledge of business methods. After graduation they normally spend several years in activities of a purely technical character, and so a postponement of the study of business methods to the post-graduate period does not adversely affect their professional careers. Indeed, this arrangement has the further advantage that it allows the student to obtain some personal contact with actual commercial life before he begins his specialized studies, and in many cases this assists him to appreciate the value of the more advanced aspects of these economic subjects.

It therefore appears that the Universities would be well advised to remove any specialized economic work that may be in their undergraduate curriculums, and to concentrate all such work into the post-graduate period. Further it is certainly desirable that some provision should be made in the undergraduate courses for the study of the basic economic and social sciences; but in view of the overcrowded nature of existing syllabuses it seems impossible to bring about this change until such time as the whole structure of the undergraduate engineering courses is revised.

However in some cases the transfer of specialized economic work to the post-graduate period would allow the introduction of a certain amount of general work on these subjects, while in other cases the economic interest of students could be whetted by maintaining an emphasis in the technical subjects on the engineer's relation to, and responsibility towards, the community. In cases where it is not possible to include any general economic work in the undergraduate period every effort should be made to encourage students to take up this work as a post-graduate activity.

The Universities, as the leading advocates of scientific methods of instruction, are in duty bound to encourage research work to bridge the gap now existing between the basic theory of these social and economic sciences and their corresponding everyday applications.

At the moment this gap is the chief factor in limiting the scope of usefulness of these sciences in engineering work. Some work has already been done to improve the position, but this field still offers many opportunities for the co-operative activities of engineering and social science research workers.

Cultural Activities.—The third main component of a balanced engineering education is one which is concerned with the cultural development of students. It is necessary to realize that

the relative importance of this section of an engineering education must progressively increase as the profession becomes more intimately associated with the life of the community. Such changes tend to bring the practising engineer before the public eye to an increased extent; in addition as engineering gradually attains to a higher professional status its members are judged not on any standard of their own but by comparison with the established standards of other professions.

During recent years these facts have been realized by a growing number of influential engineers, many of whom have criticized the Universities on the ground that the cultural background of the young graduate is often insufficient for modern conditions. This criticism has been very widespread in America, where leading engineers have affirmed that the field of interests of the average young graduate seldom extends beyond purely technical questions. While this is probably an overstatement of the general position it does contain a large element of truth. In order to overcome this disability many Universities now include cultural subjects such as English, History and Psychology in their undergraduate syllabuses, as it is believed that these studies should broaden the student's outlook on life. This hope is based on two grounds. In the first place a knowledge of the content of these subjects should enable the student to take an intelligent interest in a broader range of affairs than would otherwise be the case; and secondly it is believed that the engineering students who take these subjects will benefit as a result of the personal contacts which they thereby make with students and teachers who do not have an engineering or scientific outlook on life.

By these means it is hoped to so broaden the student's field of interests, so increase his social poise, and so develop his latent talents for self-expression that after graduation he will be able to mix freely and confidently in the general life of the community as a citizen and not merely as a technical expert. Undoubtedly this objective is a most important one; and, although the need for special arrangements to ensure its fulfilment may vary from country to country according to the standards of general education, it is itself a matter of very real importance to practically every undergraduate. Therefore it is encouraging to find that this problem is exciting a certain interest in University circles.

However it is rather doubtful whether the solution which has been outlined above is the one most suitable to modern University conditions. The major defect in this method of compulsory cultural studies is that the average undergraduate fails to realize the true significance of these subjects, with the result that they are frequently regarded merely as so many hurdles that an unsym-

pathetic faculty has placed in the course. In some cases an effort is made to lessen this trouble by allowing students to select their cultural subjects from a wide range, but even then the system is not really satisfactory.

Fortunately the problem can be approached by another method which is more suited to University conditions. This alternative approach is based on the fact that if the informal student life of a University can be sufficiently developed then the graduates of the institution will be fitted to play a leading part in the life of the community—for an active participation in this student life is undoubtedly a wonderful preparation for citizenship and for corporate life. Once these informal activities are established they quickly become part of the tradition of the University. Consequently students regard them as recreation rather than as imposed tasks, and therefore take part in them with enthusiasm and energy.

In this connection it is essential to remember that these informal activities cannot flourish if the programme of set work associated with the degree courses is unduly heavy, and in most English-speaking Universities it is unfortunately a fact that the engineering students have very little time that is free from prescribed work. Usually the whole time from 9 a.m. to 5 p.m. is taken up with lectures and practical classes, while many evenings must also be devoted to set tasks. Under these conditions it is impossible for the students to enter fully into the corporate life of the University. Thus to a large extent they miss one of the most important parts of a full University education.

However even in cases where the set programme is very full it is usually possible for a sympathetic staff to afford opportunities for the development of student activities within the department itself, and to a limited extent these can be utilized to assist in the general cultural development of the engineering students. For example students can be encouraged to form clubs and societies for the discussion of technical problems, and although these may not deal directly with cultural subjects their organization, and the preparation of papers for presentation at their meetings, afford students a general training which should assist them in after life.

But activities of this sectional nature are not sufficient—it is only by joining in the activities of the general body of students that the engineering recruits realize that their technical outlook on the problems of life is not necessarily accepted by men of other faculties. It is only by contact with men of differing types of training that they learn the art of discussing and enjoying subjects that are totally unrelated to engineering, but which are nevertheless of great importance to all citizens. All engineering

departments should therefore give serious consideration to the possibility of so reorganizing their syllabus requirements that students will be afforded an adequate opportunity of participating in the general informal life of the undergraduate body.

Duration and General Organization of Courses.—During recent years two groups of educationalists have advocated the introduction of five-year undergraduate courses in engineering in place of the shorter existing ones. But it is important to realize that the objectives of these two groups are really antagonistic. One group advocates the lengthened training because it believes that a fuller and more detailed study of technical subjects should be included in all engineering courses, while the other group is in general opposed to the introduction of additional technical studies, and advocates the longer courses only as a means of improving the general, cultural education of the students. Members of this group feel that the lengthened course would enable students to devote a larger proportion of their time either to informal student activities or to the study of non-technical subjects.

At one period certain of the leading American Universities were favourably impressed by the advocates of the lengthened engineering course, and a number of undergraduate courses were established on either five or six-year programmes. None of these experiments has proved really successful, and at the present time they play a relatively small part in the engineering educational scheme of America.[1]

To a certain extent this failure of the lengthened courses was due to the fact that they were not popular either with parents or with students, since they involved considerable problems of student maintenance, and in addition postponed the time at which students could assume family responsibilities. However, a more fundamental reason for their eclipse is found in the fact that the Universities are tending to postpone all specialized training until the post-graduate period. Once this principle is adopted a four-year course is ample for the general, basic studies that are required by the great majority of students. The men who wish to do so can enter into industrial occupations at a reasonably early age, while that smaller band that aspires towards positions of leadership in the profession can carry on their education for a further period by means of the relatively advanced and specialized courses of the post-graduate schools.

The division of the educational programme into these two sections facilitates the separation of the two classes of students. As compared with schemes which require a five or six-year train-

1. S.P.E.E.: *Report on Investigation of Engineering Education*, Vol. I, p. 136.

ing period for all recruits it also saves many of the weaker students from devoting several years to studies which would probably be beyond their effective grasp. Consequently with the growing acceptance of this organization by the Universities it is probable that four years will be adopted generally as the maximum desirable length of an undergraduate engineering course.

But irrespective of the actual duration of any course the students will obtain a maximum of benefit from their work if the component subjects are studied in a suitable order; and in this connection two main problems arise. In the first place the subjects in each basic group must be arranged in such an order that the student first obtains an adequate knowledge of the facts, theories and methods of approach that form the basis of constructive thinking in the given branch of work, and then in the later stages of the course applies this knowledge to the analysis of typical problems. Thus the best order of studies in each basic group is easily determined; but in addition it is necessary to correlate the work of the three basic groups of subjects in such a way that they will form integral parts of one educational system. Otherwise the course will lack balance, and its graduates will not be able to adequately fulfil their responsibilities as citizens and as engineers. At least two main schools of thought have developed around the solution of this second problem.

One holds that the best results will be obtained if the subjects dealing with the general cultural and social aspects of an engineer's training are concentrated so as to occupy practically the whole of the early years of the course. Usually a certain proportion of this introductory period is also devoted to subjects of a scientific nature, but care is taken that all technical studies are confined to the later years. Thus the training period is divided into two quite distinct sections. Of these the first is designed as a cultural training with a slightly functional outlook, while the second is essentially technical in its emphasis and content.

Certain definite advantages are claimed for this mode of organization. In the first place the student need not decide finally upon the nature of his career until he has reached an age at which he has some experience in the general affairs of life. Consequently it is probable that the number of misfits in later life will be reduced. A second advantage is that this scheme brings the probable engineering recruit into contact with a wide group of fellow students who have varied ambitions and widely differing outlooks on the problems of life. Consequently this early experience should help youths to realize the necessity for a wideness and tolerance of outlook on human affairs.

But this organization has at least two major drawbacks which are so far-reaching that they have prevented it from being widely adopted. In the first place it has been found impossible to arrange a really satisfactory course of this nature unless the undergraduate period has a duration of at least five years; secondly the layout of the course gives students the impression that technical work is something rather separate and divorced from the general studies.

Consequently there is an increasing tendency to arrange the undergraduate engineering courses so that the cultural, economic, and scientific stems all extend throughout the whole period. In these cases the importance of the 'scientific-technical' work is gradually increased as the course proceeds, so that the student is gradually prepared for the final transfer from the University to the outside world. Perhaps the best example of this type of layout is provided by the electrical engineering course at Yale University, a brief outline of which is reproduced in Appendix No. I.

Actually this course illustrates several other factors that are of major importance in University work. For example lectures and laboratory work are restricted to a total of fifteen hours per week, thus emphasizing the importance of allowing students adequate opportunities for free study and informal activities. Provision is also made for the inclusion of a non-technical, elective subject in three out of the four years of the course, so that students have an opportunity of studying subjects in which they may have personal interests. By these means the outlook of the student should be considerably widened, while the relatively large amount of nominally free time should be of great value in developing the initiative and resourcefulness of students as it provides an opportunity for independent study.

Chapter XIII

THE UNDERGRADUATE SYLLABUS (Continued)

Subdivisions of Engineering

IN its early years engineering was divided into two branches which dealt respectively with affairs of a military and of a civil nature; but the civil field finally became so widespread that it was convenient to subdivide it into a number of sections, each of which dealt with work of a specialized technical nature. During recent years this tendency towards increased technical subdivision has advanced considerably, so that the number of divisions that are now commonly recognized by industry is very large. But on the whole the Universities have restricted the subdivision of the undergraduate instruction to those primary technical divisions which are commonly referred to as Civil, Electrical, Mechanical, Chemical, Metallurgical and Mining Engineering.

Until quite recently this classification was universally accepted by Universities, but at present attempts are being made by some educationalists to replace this subdivision by one in which each man would be trained for a definite functional activity in the organization of the profession. Thus men would be trained for positions such as executives, research workers, sales managers, or production experts rather than as civil, chemical or mechanical engineers.

In any consideration of the relative merits of these rival methods of subdivision it is necessary to keep certain facts in mind. For example it must be realized that the lifework of most engineers divides into two rather distinct sections. During the first of these, which usually extends up to an age of 35 or 40 years, the work carried out is of a predominantly technical nature; but from this age onwards it usually becomes increasingly executive in character. However it must also be remembered that a considerable number of engineers do not leave the purely technical work, and it is worth noting that the great majority of this second class is composed of men who were not regarded as better-than-average at any time in their career.

Another relevant fact is that while members of the better-than-average group frequently move from one technical division to another, transfers of this nature are much rarer amongst those engineers who are content to remain on purely technical work. Finally due weight must be given to the fact that large companies now tend to classify their employees on a functional rather than a technical basis. Admittedly this is not so in small works; but as an ever-increasing proportion of engineering tends to fall into the

hands of the larger organizations their point of view must be given adequate consideration.

Apart from arguments based on the desirability of maintaining a traditional form of organization the chief reason advanced for retaining the technical basis of subdivision is that since engineering work divides naturally into certain technical divisions the educational system should train students for one or other of these activities. If the primary assumption be correct this is a sound attitude to adopt—as long as the subdivision is not carried to such an extent that it undermines the essential unity of the profession—but in view of facts just mentioned there are grounds for arguing that a functional type of training would meet the needs of a certain proportion of the profession more satisfactorily than does the technical method.

At the same time it must be realized that a functional organization has certain serious drawbacks. For example this type of education is of little use to men who are to remain on technical work throughout their working lives. Again it is even more difficult to determine the functional interests and capabilities of a young student than it is to form some estimate of his probable technical interests, and so the 'misfit' problem is likely to be relatively serious in a functional type of education. Also the chief emphasis in each section of such a scheme is on relatively specialized modes of thought rather than on subject matter. Consequently it is difficult for these graduates to transfer to a new functional activity. Any such change involves a reorientation of mental habits and outlooks, and it is very difficult for any grown man thus to alter his established mode of thought.

Thus while it is desirable that an effort should be made to integrate the benefits of the functional mode of subdivision into the undergraduate section of University training its adoption as the sole mode of classification would be very unfortunate. Indeed it is very desirable that Universities should re-approach this whole question of subdivision of the engineering faculty with very open minds, and in so doing they should realize that the final well-being of a profession is not advanced by an undue degree of subdivision in the undergraduate section of the associated education. It must be remembered that it is the existence of a certain body of common interests, aspirations and working techniques that provides the basic reason for a body of workers being regarded as a profession, and that the status of a profession is determined primarily by the ultimate value of these commonly-shared interests. Therefore the primary effort of the University should be directed towards developing and amplifying this common basis of professional life rather than towards emphasizing any differences that may exist between the various sections.

The general policy that the Universities adopt towards this problem is of special importance at the present time, since engineers are now beginning to admit that such basic, common ground does exist. It is gradually being realized that this basis consists of an appreciation of the scientific mode of approach to engineering problems, a skill in mathematical methods, a knowledge of economics, an ability to play one's part in the non-technical life of the community, and a desire to organize human activities and natural resources so as to improve the living conditions of society. To this must be added a knowledge of the principles of drawing—for this is the language of the profession—and an appreciation of the properties of engineering materials. These aspects of education are common to all branches of the profession, and so should form the major part of the undergraduate programme.

For these reasons it is proposed that at least the first two years of all engineering courses should be free from any technical or functional type of subdivision. This does not necessarily mean that all students should be compelled to do the same subjects during this period. On the contrary at this stage it is preferable that students should be allowed a certain freedom in their choice of subjects, because the primary objective of this part of the course should be to familiarize students with the principles and methods of science, economics and culture rather than to fill their minds with data of any prescribed character. This can only be achieved if students study subjects in which they have a live personal interest. The fact that some students may choose subjects in which the factual data is not so directly applicable to engineering problems as is that of certain other subjects is of minor importance, for any student who is destined for success in professional life will be able to make good such deficiencies by means of his individual reading in the later years of the course. But once this general background has been established it is desirable to subdivide the general body of students on both functional and technical lines. Here it is recommended that the primary mode of classification should be functional, and should aim at dividing the students into two main groups. Thus the ones who had the ability and ambition requisite for success as engineering leaders could be trained separately from those who wished to qualify primarily as general practitioners. This aspect of the problem is dealt with in another section (under the heading of 'The Outstanding Student'). All that needs to be mentioned at this stage is that the undergraduate education of these students should be kept as broad as possible and that it should emphasize the responsibilities and duties that are shared in common by all engineers

rather than the differences in technical outlook that subdivide the profession. These students will have adequate opportunities of obtaining specialized knowledge through the medium of post-graduate courses.

The position of the 'general practitioner' group is substantially different from that of the leaders, since the former group is comprised of students who will probably spend the major part of their lives in a given technical branch of engineering. Consequently it is desirable that this group should be subdivided on a technical basis into civil, electrical, mechanical, chemical, metallurgical and mining sections. Therefore the final years of their undergraduate training should be designed to provide a moderate amount of specialized knowledge in the appropriate branch of engineering.

A certain number of important American institutions have been experimenting with another functional type of course. This is usually referred to as 'Administrative Engineering' and is conducted parallel with existing technical subdivisions. At present it is difficult to estimate the importance and the permanence of the innovation, but it certainly merits consideration. Usually these courses place less emphasis on the basic scientific and the advanced technical subjects than is the case in the technical subdivisions. Apparently the chief objective is to carry out a rather detailed study of business and administrative problems against a background of general engineering techniques.

These courses are very popular with students of average rather than of high ability, and this is probably explained by the fact that the standard is usually lower than that which is maintained in the older engineering courses. From an engineering viewpoint this is most unfortunate, for if the profession is to advance it is essential that its executive positions should be filled by men of superior natural ability who have received a thorough training in the scientific, technical and cultural aspects of the profession. Therefore it is to be hoped that administrative courses of this nature will not become firmly established as part of the undergraduate organization. Further support for this contention is provided by the fact that normally engineers do not enter administrative positions immediately after graduation, and so the study of administrative problems can conveniently be postponed till the post-graduate period.

Practical Experience in Engineering.—One of the oldest and most important problems associated with engineering education is that of correlating the theoretical training of the schools with the practical experience of the actual works. At the present time this problem is of ever increasing importance since the Universities are

placing a growing emphasis on basic theory rather than on practical information. In this connection there is no conflict of opinion as to whether practical experience forms an essential part of an engineer's training, but there is a considerable divergence of opinion as to when and how this experience can best be obtained.

The objectives of practical experience may be summarized as follows: This training should familiarize recruits with industrial processes and procedures; it should acquaint them with the working capacities of men and of machines; it should develop their sense of size and proportion; and it should widen their social outlook and develop their personalities and powers of initiative. At all times it must be remembered that the primary objective of this practical experience should be to develop a background of experience that afterwards will assist these men in their advanced professional activities. Under no circumstances whatsoever should the development of mere personal proficiency in production methods be regarded as its major objective. Indeed the most important fact that must be kept in mind when organizing these activities is that the training should be carried out in such a way that recruits will not tend to lose that scientific outlook which they should have acquired as a result of their theoretical training. The maintenance of this mode of thought is essential for all real success in professional life.

In the earlier days of English engineering it was commonly held that all theoretical training should be preceded by at least a year of works' experience to enable the student to appreciate the practical techniques involved in engineering. Probably this was justifiable in those early days, for then engineering was a trade rather than a profession; but now that engineering practices are based on the sciences the introduction of a prolonged period of works' experience between the secondary school and the University is to be deplored. Admittedly such experience will give the student a certain understanding of the trade processes associated with engineering work, but at the same time it will do much towards breaking down habits of study and modes of thought that would otherwise be of great value to the student in his University work. Also in these conditions the student's lack of knowledge of the scientific principles underlying the practical work prevents him from distinguishing between practical procedures which are fundamentally satisfactory and ones that are not. Consequently experience obtained at this stage may easily give the recruit a very unsatisfactory set of standards.

It is therefore reassuring to find that the modern tendency is to postpone all prolonged periods of works' experience until the completion of the theoretical training. When the experience is

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obtained at this latter stage the young recruit will have an adequate background of scientific and general knowledge before he enters the works, and this will assist him in making a critical examination of the works' procedure. Also he will have sufficient confidence in his own judgment to disregard practices which he may regard as being either fundamentally unsound or of an unduly empirical nature.

In cases where recruits have to obtain their works' experience under ordinary working conditions it is most desirable that this practical period should come after the completion of the University work; but if it is possible to arrange for an adequate degree of co-operation between a University and some suitably located, and progressively minded, manufacturing company it may be feasible for the theoretical instruction and the works' experience to be conducted in conjunction. This type of procedure has been developed chiefly by American Universities, and just before the recent industrial depression some 10 per cent. of the engineering students of that country were working under some form of 'co-operative' scheme.

These courses divide into three classes according to the nature and the extent of the co-operation that is obtained between the University and the industrial firms associated with the scheme. In the first class the co-operation between the parties is of a very high order since the aim of these courses is to integrate the work at the factory into the curriculum of the University in such a way that the practical experiences will always be logically and closely related to the theoretical instruction that has just been given at the University. Indeed in some cases provision is made for the theoretical instruction to be continued during the 'works' periods. Thus in this type of course the works really become an extension of the University, and students remain in a professional atmosphere throughout the whole of the course. Consequently this type of co-operative training normally gives excellent results; but such courses can seldom be established. They require the closest possible co-operation between a University which possesses a very adequate staff, and a large, conveniently located works which is controlled by men of considerable vision.

In the second class of co-operative course theoretical and practical periods alternate with one another. In these cases the industrial company merely accepts the students into its works under normal working conditions and arranges for them to pass gradually through the various departments Usually some special officer is detailed to supervise the scheme on behalf of the University, but no special efforts are made to correlate the works experience with previously studied theory.

This type of course is of much more frequent occurrence than is the first; but the standard of training falls very much lower. Admittedly the 'works' periods broaden the students' outlook on life, and increase their knowledge of certain engineering procedures, but the course as a whole lacks that continuity of emphasis on the use of the scientific method as an engineering tool that is essential to all truly professional types of training. Consequently these 'sandwich' courses will gradually decrease in importance as far as the professional level of engineering education is concerned, but at the same time they should be of considerable value in the vocational section.

In addition to these types of co-operative courses a third method has recently been developed by the chemical engineering sections of certain Universities.[1] Actually this procedure is most frequently found in connection with post-graduate work, but as it can also be applied to undergraduate courses it is considered at this stage. In this type of co-operative education the students do not pass under the control of the industrial company during their time at the works, and the scheme actually involves the temporary transfer of certain parts of the works to the University authorities, who utilize them as laboratories in which to carry out full scale tests and research work. Under this scheme there is no interruption in the presentation of the University work, since the same instructors remain in charge during both sections of the course. The experience of institutions which have tried the method indicates that it gives very satisfactory results.

In view of the considerable number of students included in the various American 'co-operative' courses an observer might tend to attach undue importance to this method of correlating the theory and practice of engineering. It is therefore necessary to point out that only a small proportion of the co-operative courses belong to the first of the above sub-classes, and it must be remembered that these are the only ones that fulfil all the requirements of the theoretical and the practical sides of a professional type of engineering education. It must also be remembered that the success of an otherwise satisfactory co-operative scheme may be completely wrecked through the occurrence of an industrial depression—for under these abnormal conditions the industrial partner to the scheme is often unable to carry out its share of the work effectively.

Consequently, although there are numerous examples of successful co-operative schemes, it is unlikely that this type of organization will become the major method of correlating the practical and the theoretical sides of engineering education. Indeed with the

1. See S.P.E.E. 'Report on Investigation of Engineering Education,' Vol. I, p. 564.

ever-increasing importance of scientific and social studies as the basis of an engineering training it seems certain that the works' experience must become an exclusively post-graduate activity.

Most Universities have already adopted this view; but up to the present the general body of employers has not accepted it as a desirable state of affairs. Indeed many small employers still feel that graduates should be well versed in practical details at the conclusion of their undergraduate career, and they make no provision for teaching their recruits this side of their professional lore. In the large companies the position is usually quite different, and many progressive firms have established training schemes which are specially designed to put young graduates in touch with the practices and procedures of industry.

But as yet many employers have not realized that the practical training of graduates is their special concern, and that the provision of adequate facilities for this work forms no more than their just contribution towards the educational system of their profession. Consequently it is most desirable that the appropriate authorities—namely, the Universities and the professional engineering Institutions—should undertake an active campaign to improve this position so that future graduates will be assured of adequate facilities for practical training. However this is really a post-graduate activity, and its fuller consideration is postponed to a later section.

The Non-Graduating Student.—During recent years considerable attention has been focussed on the facts that in many Universities the percentage of failures in engineering has been unduly high, and that this percentage has shown a tendency to increase. In America an investigation[2] by the Society for the Promotion of Engineering Education showed that only 30 per cent. of engineering students graduated within the normal four-year period, while less than 40 per cent. of the entrants ever graduated in engineering. Although the results of such extensive investigations are not available for other English-speaking countries it appears that similar conditions are fairly widespread. This wastage of from 60 to 70 per cent. of the entering students is of serious import, not only to the students who fail to graduate, but also to the Universities, to the profession of engineering, and to society as a whole. The continuance of such a high rate of mortality will undoubtedly react unfavourably on all these bodies. The Universities as the teaching body concerned will suffer in prestige, since an efficiency of from 30 to 40 per cent. is not a fact that the public will continue to overlook; the profes-

2. See S.P.E.E. 'Report on Investigation of Engineering Education,' Vol. I, p. 193.

sion will lose the services of many suitably talented men, for the high percentage of failures will undoubtedly deflect many potential engineering students into other lines of study; and society as a whole will suffer both as a result of the decreased effectiveness of the engineering profession, and also because many of the 'failures' will not be able to fit themselves into any very effective work.

Undoubtedly the primary reason for this unfortunate condition is that many youths who enter upon a University engineering course are not suited—either by temperament, training, or natural ability—for this type of professional training; but a second reason is that most engineering courses endeavour to cover too much ground in the time that is available. Consequently if the position is to be materially improved it will be necessary to solve certain problems associated with pre-University training, with admission to engineering courses, and with the content of these courses. Each of these topics has been discussed in earlier sections; thus all that is now required is a brief review of the outstanding points.

The pre-University training is of importance for two reasons. In the first place it is found that a considerable percentage of the failures in an engineering course are directly attributable to the fact that many students fail to realize that they must arrange their own programme of work. Consequently it is desirable that secondary schools should throw their senior students on their own responsibility as much as possible. A further fact that contributes to the long list of failures is that the pre-University training has often failed to give oncoming students any very clear or adequate conception of the intellectual disciplines that are associated with the undergraduate courses for the various professions; consequently many youths begin an engineering course at the University without being adequately aware of the nature of the work that lies ahead of them. Again in this case the schools themselves could do quite a lot to improve this position, but if this problem is to be completely solved it will be necessary for the Universities and the various professional societies to provide the schools with detailed information on this question.

Also the percentage of failures would be considerably reduced if the existing entrance requirements of the Universities could be supplemented by some test which would indicate the probable technical interests and talents of the prospective students. At present several American Universities are experimenting with entrance tests of this nature; and a comparison of the predictions made on the basis of these tests with the actual performances of the corresponding engineering students indicates that these methods will probably become of considerable value in

the near future. If this hope is realized it will do much towards reducing the number of misfits in the technical faculties.

However it must be admitted that, although the foregoing are very real factors in the problem of engineering failures, the chief cause of the trouble usually lies within the University course itself. Consequently unless this can be revised in such a way that students will be allowed a considerably increased amount of free time, engineering will continue to hold an unfavourable position as far as its percentage of failures is concerned. Therefore it is essential that every possible opportunity should be taken to relieve the undergraduate courses of the specialized subject matter that they often contain, thus allowing students an adequate opportunity to become really conversant with the more basic knowledge.

The Outstanding Student.—With the growing importance of the advanced phases of professional engineering work it becomes increasingly desirable to provide a special type of education for the 'better-than-average' students. These are the men who will finally fill the leading positions in the profession. Until recently this need was not catered for to any considerable extent; but at the present time some institutions are beginning to pay increased attention to the needs of unusually brilliant students, and plans are being developed which will allow these men to advance at a rate commensurate with their actual ability.

In countries that are well provided with high-class Universities this need can easily be met by providing separate institutions for the education of the 'leaders' and of the 'general practitioners,' so that each University will have a single educational objective. Examples of this type of organization are to be found in the United States; and the chief criticism that can be levelled against the plan is that students must be graded into one or other of the two classes at the conclusion of their secondary education. Consequently it is probable that the widespread adoption of this system would give rise to a considerable number of misfits; and provision would have to be made for transferring students at the end of the first year of their University course. But on the other hand this scheme provides each class of University with recruits of a fairly uniform standard, and so the advanced classes need not be held back for the benefit of students of relatively poor ability. Therefore it is easy to keep the whole of the advanced course on a highly professional standard.

However, the adoption of this scheme pre-supposes the existence of other conveniently located Universities which would be willing and able to provide for students who expect to become general practitioners rather than leaders. Also it assumes that the institutions which adopt the higher standard of instruction are so

endowed that they can afford to deprive themselves of the fees of the less brilliant, but relatively numerous, students.

Consequently it is not always feasible to provide for the brilliant students in the above manner, and in such cases the only alternative is the establishment of two levels of instruction at each University. Frequently this is done by providing 'Honours Courses' parallel with the already established Pass ones, thus introducing into the engineering system a method which has already proved successful in other sections of the University. Normally the basic objective of these Honours Courses is to throw students on their own responsibility, so that they will be forced to think and plan for themselves to a greater extent than is usual in the Pass Courses. The syllabuses are designed in such a way that students must direct their work towards understanding the underlying principles rather than towards acquiring mere factual knowledge.

In most cases these Honours Courses in engineering are restricted to the final two years of the undergraduate course, since the general basic studies of the earlier years are equally valuable for both types of students.

This procedure also enables members of the staff to become fairly well acquainted with the latent talents of the individual students before the final subdivision into the Pass and Honour groups is carried out. Thus the danger of creating misfits is greatly reduced. Normally the students who are selected for the Honours group are freed from set routines and rigidly prescribed courses of study, and are placed as far as possible on their own responsibility—since one of the chief objectives of such courses is the development of initiative, resourcefulness and self-reliance.

For example these men are not required to carry out a number of relatively small laboratory experiments, the details and sequence of which have been arranged by some member of the staff; instead they are expected after consultation with the appropriate lecturer to develop a logical programme of laboratory work which will enable them to investigate some fairly broad engineering problem. Again these Honours men are encouraged to replace the formal lectures of the Pass Courses by individual reading and by regular Honour group meetings at which the students discuss papers that they themselves have prepared. Normally the University provides a special staff-member to supervise the work of the group, and in addition all the Honour group men are encouraged to develop intimate contacts with members of the general teaching staff.

Thus the work is conducted in a tutorial rather than a lecture atmosphere, and provides considerable opportunity for developing individual personalities. Also since the members of the Honour groups have been selected from the general body of second year students because of outstanding personality, ambition or talents

they are able to extract the greatest possible assistance from the atmosphere of individual endeavour, duly tempered by mutual co-operation and criticism, which characterizes the final years of their undergraduate careers. Thus it is probable that their latent powers of leadership and their capacities for individual mental effort will be developed to a greater extent than would have been the case if these students had remained in the ordinary type of Pass Course, for there the atmosphere would have been primarily one of mass reception of information.

But if an Honours type of education is to be satisfactorily developed in any institution it is essential that certain conditions be fulfilled. In the first place it must be remembered that no such scheme can succeed unless the correct type of student is selected for its classes. In this connection the importance of personality and ambition cannot be too strongly emphasized. For this reason the choice of students must be made on the basis of personal qualifications as much as on examination records. A second important condition is that the institution must have an adequate and suitably trained staff available for tutorial activities and for the general oversight of the Honours Group scheme; and in addition all these men must be prepared to take a personal interest in the work and general activities of the Honour students.

It is also essential that staff, students and employers should all be convinced that the Honours type of training provides the best possible preparation for a successful professional career. In most cases staff and students will quickly adopt this attitude, but often it will be difficult to move employers from their established modes of thought. The only way of achieving this is to insist on the Honours Group maintaining a standard of achievement that is definitely in advance of that of the Pass Group; great emphasis must therefore be laid on the necessity of all Honour men being grounded thoroughly in science and mathematics.

At present employers are beginning to realize that industry needs recruits who are capable of independent thought along scientific lines, rather than ones who are merely equipped with a vast accumulation of detailed technical knowledge. Actual experience with the two types of recruit has shown these employers that, whereas the latter type may be more useful immediately on engagement, it is the man who has been well grounded in the scientific method of approach and whose personality has been thoroughly developed by the informal side of a University education who takes and maintains the lead after some twelve or eighteen months of works' experience. The demand for this type of graduate will be a gradually increasing one, and so it is reasonable to expect that the Honours Group type of training will become of great importance in University work.

Chapter XIV

POST-GRADUATE ACTIVITIES

FOR a variety of reasons the importance of post-graduate studies has increased greatly during recent years. In the first place an ever-increasing proportion of the undergraduate course is being devoted to basic studies in science, economics and cultural subjects with the result that specialized technical work tends to be postponed to a later period. Secondly, in order to keep up with modern developments in the basic subjects it is necessary for practising engineers to continue their studies on a systematic basis. Finally, the growing professional status of engineering makes it desirable that all active members of the profession should develop their knowledge of social and business problems as much as possible. Thus it is certain that the importance of post-graduate work will continue to increase, and that the majority of future engineers will engage in prolonged periods of post-graduate work.

This advanced work divides into three main fields. The first comprises that practical experience which all graduates must obtain before they can be regarded as competent engineers; the second consists of specialized scientific, technical and administrative training; while the third trains men for the general problems of community life. In order that these various activities may be integrated into the life of the profession it is necessary that the advanced training should be controlled by some representative body which enjoys the confidence of the engineering world. This need can be partially met by the establishment of advanced engineering degrees under University control, but this caters only for that section of the profession which has received a University education. Thus it is desirable that the Institutions of Engineers should interest themselves in the question of post-graduate training for all types of engineers. Once their interest has been roused these institutions could control the advanced work quite effectively by restricting their upper grades of membership to men who had reached a satisfactory standard in the three main fields of advanced work. This method of control has been very effective in professions such as medicine; and it is interesting to note that this procedure forms an important part of the attempts which are now being made by American engineering institutions to obtain a recognized status for the profession.

These institutions are now engaged in organizing "continued-studies" amongst their members, in integrating the advanced work of the Universities into a general national scheme, and in readjust-

ing their membership requirements in order to give due recognition to advanced studies and experience. This work is of very considerable importance; and its detailed characteristics will be evident from the general review of advanced engineering activities given in the following sections.

Works Experience for Graduates.—Theoretical knowledge and practical experience can best be correlated by regarding the latter as an essentially post-graduate activity. For real success this procedure requires the whole-hearted co-operation of employers, since the young graduate cannot make a really efficient use of this training unless the employer sets up some organization to assist him. In England and in America leading engineering firms have done much in this direction by establishing training courses. These are controlled by specially selected engineers who devote their whole time to this work. Graduates enter these courses direct from the Universities, and in a period of from two to three years obtain experience of workshop procedures and test methods. They are also introduced to the simpler aspects of design work and of commercial activities, and in addition the trainees are usually afforded special opportunites for continuing their theoretical education. Frequently their general progress in these various activities is utilized as a means of distinguishing between these men when vacancies occur on the professional staff of the company.

In some progressive companies very extensive facilities are provided for the continued theoretical education of a specially selected band of these young graduates; and in some cases these men spend at least half of the working week in a post-graduate school which is maintained by the company. The rest of their time is divided between the design and test sections of the works.

Unfortunately the maintenance of any definite scheme of works-training for young graduates is an expensive affair, and can only be efficiently organized if the works concerned are of considerable size. Consequently many young graduates now find it impossible to enter any such organized scheme of training, and are forced to pick up their practical experience while holding subordinate positions in small firms. This is most unsatisfactory; and its continuance will discredit the University approach to a professional career in engineering. The modern University system of engineering training is based on the assumption that graduates will obtain an adequate training in practical procedures immediately on leaving the University, and the non-validity of this assumption will have most serious results.

Hence it is necessary that steps should be taken by some competent authority—such as the national professional societies—to organize schemes of practical training for men who otherwise

would not have the opportunity of enrolling in a controlled scheme. Probably the most effective way of achieving this would be by an extension of the training facilities already maintained by the larger firms—it being understood that the additional costs would be covered by levies on the smaller firms which would benefit from the improved training facilities. Admittedly the difficulties of organizing and policing such a scheme would be considerable; but the only alternative is to establish co-operative training schemes amongst the smaller companies.

A further factor which must be taken into account in this question of practical experience is the growing importance of government departments as engineering employers; in the future these units will probably be called upon to play an increasing part in the provision of practical training for young graduates.

Admittedly any scheme which aims at improving the facilities for obtaining practical experence will lay an increased direct charge on industry; but industry cannot progress unless the oncoming engineers receive an adequate training. The initial cost of such schemes is undoubtedly high, but it is considerably offset by the increased speed at which the young graduates become of actual financial value to their employers.

Advanced Studies for Men in Employment.—This is probably the most difficult field to cover effectively for it deals with a membership which has a very uneven educational background. Actually this difficulty will decrease as time goes on, since the majority of engineering recruits now enter the profession through the Universities; but at present the position is quite involved. Some men have entered the profession through a purely practical training, while others have the theoretical background of a University career. Consequently both the subject matter and the mode of presentation of the advanced courses must be varied considerably according to which of these two groups is under consideration. The graduate group as a whole is the better informed in theoretical matters, but the non-graduates usually hold the advantage in questions of practical procedures and workshop techniques.

The organization of this type of work is also complicated by the fact that it is subject to dual control by the Universities and the professional societies. Therefore all schemes of advanced work must provide for close co-operation between these two groups of institutions, so that the whole field may be effectively covered without undue overlapping. At the present time the major emphasis in any plan of advanced studies for men in employment should be laid on the part to be played by the professional institutions since these bodies have as yet not fully realized their responsibilities

in this connection. Also it must be remembered that the bulk of the men now requiring this type of instruction have no direct connection with the Universities.

Therefore it is interesting to find that the various American Institutions of Engineers are now taking active steps to popularize continued education in technical, economic and social subjects. In order to further this work the joint committee, which is organizing these activities, has recently issued a personal questionnaire to the members of the co-operating bodies. This document emphasizes the necessity for continued study in a wide range of subjects, and is so designed that the answers to its questions outline an adequate plan of studies for the individual concerned. Further, a well-chosen list[1] of general and technical reading is issued with the questionnaire so that members will be able to improve their knowledge by individual reading even if they cannot attend any formal class of advanced instruction.

Although such schemes of self-advancement are most praiseworthy they are not in themselves sufficient to meet the situation, and it is probable that the Institutions will finally have to undertake more active procedures—such as the organization of correspondence courses, and series of lectures—to meet the needs of the non-graduate section of their membership. If any large proportion of the non-graduates is to be drawn into these educational schemes it will also be necessary for the Institutions to offer some direct incentive towards this advanced work. Possibly this could be done by making this type of work a pre-requisite for the award of the Institutions' corporate membership. In America a proposal is already afoot whereby this grade of membership would be restricted to men who had successfully completed an examination in technical, economic and cultural subjects. This examination would be of a standard higher than that of University graduation; and would be designed to show that successful candidates had sufficient ability to be safely placed in charge of responsible engineering work, and that their general training was of such a nature that they could take a reasonable part in the general life of the community.

The Universities could well assist in organizing the theoretical side of these studies; but it is undesirable that such co-operative activities should be regarded as the chief contribution of the Universities to this type of training. Actually the primary duty of the Universities is to the graduate section of the profession and any part-time training that they sponsor should be designed primarily as an extension of their full-time post-graduate activities.

1. See *Electrical Engineering*, Vol. 53, p. 1667, and Vol. 54, pp. 133, 345, 456, 569, and 681.

Two main fields of part-time advanced training are open to the Universities. First there is a group of activities; such as vacation schools and evening lecture courses, which aims primarily at providing an opportunity for employed graduates to keep abreast of modern advances in the basic sciences, in mathematical methods applicable to engineering practices, and in the specialized theory applying to detailed branches of engineering. Normally work of this nature would not count towards higher degrees (since these courses are really intended as 'refreshers') but attendance could well be made a partial qualification for the higher grades of membership of the professional Institutions.

This type of work would cover cultural and economic subjects as well as ones of a purely technical interest. By the time they reach an age of forty years about two-thirds of engineering graduates occupy administrative positions, rather than purely technical ones; and so commercial and administrative problems would form very suitable topics for these courses.

However, it is necessary to realize that under present conditions most engineers tend to remain in administrative positions where the major emphasis is on technical considerations. They are generally less successful in obtaining managerial positions where a knowledge of finance, of legal procedure, or of human nature, is the key factor. This is due very largely to the nature of the engineers' early training. This makes them think quantitatively, analytically and impersonally, so that they tend to underestimate the importance of intangible, immaterial factors, such as public opinion and personal interests. Also their training in science tends to make them unduly cautious when confronted with problems of a non-scientific nature; they postpone decisions until further information is available, whereas for success in many administrative positions it is often necessary to make bold decisions before the detailed information is available.

Consequently when the engineer seeks a general executive position he is often at a disadvantage as compared with the legally or commercially-trained man. Therefore any post-graduate training that the Universities may develop in the administrative field should deal with more than the problems of business procedure. This knowledge is important; but it must be supplemented by an adequate understanding of human beings, both as individuals and as groups.

The second field of part-time, post-graduate education in which the Universities can play a part is that which provides an opportunity for the employed graduate to qualify for an advanced degree. Up to the present this field has not been very much developed, and a review of the position indicates that it is one which Universities should enter with considerable caution.

This work divides into two sections, according as to whether the advanced course is conducted in 'evening' classes or is organized on a 'co-operative' basis. Evening classes are unsatisfactory even in the vocational schools, and when this educational method is transferred to the post-graduate field its disadvantages become so pronounced that it is difficult to see how it can be regarded as a desirable path to an advanced degree. Admittedly a brilliant intellect will be able to utilize a course of this nature as a means of obtaining a mastery of the technical knowledge associated with certain specialized aspects of engineering work; but it will be impossible for such students to establish those intimate contacts with staff-members and with fellow-students which should form an important part of any University degree course. Indeed it seems very unlikely that students who obtain their advanced education at an 'evening University' will ever regard education as anything more than a means of advancing their personal interests.

Under the 'co-operative' type of organization the conditions are much more favourable for the development of scholarly work—for here the graduate's primary interest is in his educational work, whereas in an evening course the studies are merely an extra activity that is crowded in at the end of the real day's work. The effectiveness of these co-operative courses depends primarily on the degree of co-operation that can be effected between the University and the works; and to achieve a real success this must be such that graduates will be working in an educational atmosphere rather than an industrial one. American experience[2] shows that courses of this nature can give excellent educational service, but on account of the difficulties associated with their organization and maintenance it is unlikely that they will be very extensively adopted for advanced work.

Full-time, Post-graduate Work.—Since full-time, post-graduate work is usually a continuation of the undergraduate courses this field has been occupied almost exclusively by institutions of University standing. In some lands the professional Institutions of engineers have also interested themselves in this type of educational activity—the most important example of this being found in France, where a number of post-graduate colleges have been established by the corresponding professional bodies. The first of these—École Superiéure d'Electricité—dates from 1894. This institute was built and equipped by the electrical industry, and is organized as a non-profit corporation which is administered by a commission representing the Institution of Electrical Engineers, the subscribing industries, the University of Paris, the École

2. E.g., "Pitt-Westinghouse" Course, see *Electrical Engineering*, 1934, Jan. and April.

Centrale, and the staff of the Institute. This college draws its recruits from the technically-trained graduates of the Ecole Centrale, and provides post-graduate courses in different aspects of electrical engineering.

A further example of the interest that the professional societies are now taking in post-graduate work is afforded by the fact that certain of these national bodies now subsidize selected research activities at the Universities. This widens the scope of work that the Universities can handle and at the same time keeps the professional Institutions in intimate contact with the educational work of the teaching bodies.

Thus it is probable that the professional societies will finally play an important part in organizing full-time post-graduate activities; but at present this field is left mainly to the Universities.

Probably this type of work reaches its volumetric maximum in the United States, where between 10 and 15 per cent. of each graduating class now return to some University for post-graduate engineering study. These full-time courses of advanced study vary in duration from one to three years, and the successful completion of this work is recognized by the award of one of the higher engineering degrees.

In the better class of post-graduate training each scheme is divided into two sections. One is designed to develop the analytical ability of the student by presenting him with technical problems which are to be solved by an orderly application of scientific and mathematical methods; the other endeavours to develop the student's powers of creative imagination through a programme of research activities. Almost all Universities give at least lip service to this mode of organization; but in many cases the activities which they class under the first of the above sections are directed more towards imparting specialized information in a number of rather unrelated courses of study, than towards developing the student's mind into a tool which can deal successfully with unusual types of problems. Also there is such a wide variation in the nature of the work that the Universities class as research that it is necessary to consider what should be the real nature of this activity.

In the first place it must be realized that there is no vital distinction between what is called 'engineering research' and any other type of research. In fact the common use of this term is most unfortunate, for research cannot be divided up into component parts. Research is, or should be, a search after any form of truth that previously has not been understood by mankind; and the pursuit of research involves a willingness to interest oneself primarily in the 'fact' itself and the associated 'laws,' rather than in the application of this fact to some practical end.

Probably it will be objected by some that this means that there is no such thing as 'engineering research' as distinct from 'scientific research,' and to this the author must agree. But this is very different from affirming that there is no field of research that is of special interest and value to engineers. Actually there is a wide field of this nature. Admittedly it overlaps at many points with fields that are of special interest to the physicist, the chemist and other types of scientific worker; but this is only natural for fundamentally engineering is based on scientific modes of thought. But although this overlap exists it will usually be found that the engineer who is engaged on research work relating to a certain 'fact' tests its nature by subjecting it to controlling, or disturbing, conditions which differ materially from those which would be chosen by a worker whose primary interest was in some other branch of science. Thus the real difference between the fields of research is not found in the nature of the 'fact' that is to be investigated, but in the character of the relevant laws in which the worker choses to interest himself.

For example, the switch-gear engineer is primarily interested in the laws controlling the extinction of the electric arc; whereas a chemist working on arc phenomena would be interested chiefly in the manner in which the arc affected the properties of different materials. Thus a single primary 'fact' can well be included in a large number of fields of research.

However, the really important point to be remembered is not that different men will work in different 'fields of research,' but that all such workers must approach their work with the same attitude of mind—namely, a determination to find the basic reasons and laws that control a given phenomenon.

In many cases the work which is classified as research by the engineering departments of Universities is not of this fundamental nature; it tends rather to fall into the classifications of tests or of investigations. For example a great amount of valuable work has been done in determining the strength and other physical properties of engineering materials, and frequently this type of work is classified as research. However, it is merely a type of testing work, and is of little or no value as a means of developing the minds of advanced students. The engineering investigation is an activity that is intermediate between testing and research, and is of a rather indefinite nature. However, in most cases it consists of a combination of empirical experiments and routine testing, and under those conditions is certainly not of a research nature. But at times this work does lead to true research activities; and if care is exercised in the selection of topics it is not altogether unsuitable for advanced students.

Although no inclusive figures can be produced for the costs of post-graduate education the amount required per student-year is undoubtedly much higher than that necessary for an undergraduate training. Some idea of the magnitude of the problem can be obtained from the fact that in 1925, when the total post-graduate enrolment in American colleges amounted to only 12 per cent. of the number of bachelor degrees conferred during the previous year, the cost of the research section of the post-graduate work amounted to 5 per cent. of the total outlay on the four-year undergraduate courses. The investigation[3] which was made then also showed that many Universities were unable to support any real research activities; that seven-eighths of the total post-graduate enrolment was associated with a group of ten Universities; and that this group of colleges was responsible for 75 per cent. of the total research expenditure.

This tendency to concentrate post-graduate activities at a relatively small proportion of the Universities is a natural one, and undoubtedly is due largely to the high costs of providing the necessary equipment and of retaining staffs of suitably trained lecturers. In order to reduce these troubles there is now an increasing tendency for the leading Universities to divide the fields of post-graduate work in such a way that duplication of effort is avoided. Under this scheme each institution covers a relatively narrow field in this work, and its post-graduate staff can therefore be made relatively homogeneous in outlook and interests.

A further important result is that the system encourages the migration of senior students to Universities that specialize in their chosen subject. This widens the students' outlook both by the formation of new personal friendships, and by bringing them into contact with fresh outlooks on technical questions. However, in non-residential institutions these migrations may cause some students considerable financial hardship, since they may have to live away from home for several years. Consequently it is desirable that such systems should be accompanied by adequate scholarship or bursary schemes.

Up to the present the general advance of research work has been severely limited by two factors, namely those of trained personnel and of finance. To a large extent the first of these limitations will be removed by the adoption of dual objectives in the undergraduate course, and by the establishment of adequate post-graduate facilities; however, the second one will remain a matter of serious consideration until such time as the community realizes that research must either be adequately endowed from public funds or else be so related to its own results that it will be self-supporting.

3. See S.P.E.E. *Report on Investigation of Engineering Education*, Vol. 1, p. 321.

In some cases where individual research workers have retained the financial control of the industrial processes based on their research this second mode of support has been successfully introduced by earmarking a percentage of the industrial profits for further research work. But although this method may be feasible in isolated cases the lag between the discovery of a principle by the research worker and its application to a successful industrial process is often so long that it would be very difficult to apply this principle to the general support of research. Its sphere of usefulness seems to be limited to certain special cases. Thus it would appear likely that research will have to be supported by subsidies from the public funds. But at present few governments realize the importance of research as a factor governing the future prosperity of the community and their support is usually so inadequate that the Universities are forced to seek other sources of financial assistance.

Thus some institutions are tending to develop co-operative relations with industrial concerns that are likely to benefit from the proposed research. At first sight this appears a very desirable development; but it is necessary to realize that the interests of the University and those of the industrial concern are frequently very divergent. For example while industry is normally, though admittedly not exclusively, interested in obtaining results which will be of immediate value in its productive activities, the University is primarily interested in work of a more fundamental nature, such as the determination of new laws and facts. Again while the University desires to publish the results of all research work as soon as possible many commercial firms wish the publication to be delayed as long as possible so that they may reap the financial benefits associated with any new discovery.

Thus in spite of the manifold advantages associated with the co-operative type of research work—such as adequate financial support, increased industrial experience for University staff members, facilities for large scale tests, and the establishment of cordial relations with industrial concerns—it seems inadvisable for Universities to adopt this procedure immediately as their regular mode of financing research. In cases where the industrial concern is broadminded enough to forego its immediate interests in favour of those of the community as a whole, co-operative research will certainly be an activity into which the University can enter with enthusiasm. The number of firms with this type of outlook is gradually increasing, and consequently this mode of financial support will probably be of ever-increasing importance. But in their search for financial support the Universities must always remember that they are representatives of the community as a whole and not the servants of any sectional interest.

Chapter XV

CRITICISM OF UNIVERSITY ENGINEERING EDUCATION

CRITICS are far from unanimous in their remarks about the existing scheme of professional engineering education; but they divide into two main groups according to their professional experience and outlook.

The first group usually consists of relatively young and fairly old graduates who assert that the existing courses do not lay sufficient emphasis on the practical aspects of the profession. To a certain extent these critics also complain that insufficient attention is paid to business methods and administrative problems. Little attention need be paid to these criticisms since the activities advocated are essentially post-graduate in nature and it is undesirable that they should be included in undergraduate courses.

The criticism offered by the second group is much more important for it contends that most existing courses produce graduates with insufficiently developed powers of thought. It is significant that this criticism usually comes from engineers who are in the prime of their professional career and who are in intimate contact with recent graduates. These active leaders of the profession charge the modern graduate with an inability to tackle independent work or to develop new ideas. They also frequently add the criticism that the graduates' outlook is often limited to purely technical interests, and that their personality and general social attributes are insufficiently developed.

This outlook is clearly expressed in an article[1] by Dean Doherty, of Yale University, who before his present appointment was in charge of the 'Advanced Course' of the General Electric Co. of America.

'From personal experience, extending over a decade, in examining and following the professional progress of very large numbers of electrical and mechanical engineering graduates from over a hundred engineering colleges, it is my studied observation that they have acquired at college notable facility in certain routine engineering techniques; that they have in memory a large body of engineering information; that their long drill and experience in careful measurement and numerical calculation have engendered in them a quantitative sense, a profound respect for a fact, and habits of thoroughness, orderliness, and accuracy, all of which are distinctive attributes of a scientific, professional mind.

1. *Journal of Engineering Education*, September, 1934, p. 28.

'However, with all these recognized values, their college courses have left most of them at graduation mentally clumsy, relatively narrow in interest and perspective, and awkward in writing and speech. Their minds have not been sufficiently disciplined in straight thinking, and consequently they are lost when they encounter a problem which does not conform to certain special types. They are practically incapable of analyzing problems or situations in terms of general principles. They think narrowly in terms of special formulæ and specific cases. Moreover, under the pressure of time they have not developed a real interest in other vital aspects of life. Without an historical perspective, with little knowledge and almost no interest in the thoughts and lives of great thinkers in other fields, engineering graduates have tended to remain in the comparative isolation of technology. Now the sin of professional isolation is not confined to engineering; the same charge, it seems, might be levelled with justification at any of the other professions. But it becomes especially significant in the case of engineers because their technological advances have created, and will continue to create, a new world in which people have to live; and that world should not be patterned with reference to physical forces alone.

'Now I realize that this is a very broad and critical statement. I should hope that it would not be interpreted as condemning as futile the carefully studied policies and programmes of engineering education in America. I do not have to recall to you the great contributions which engineers who graduated from those programmes have made toward the progress of technology. The simple fact is that in providing a training for the routine operations of engineering these programmes at the same time have opened the *possibility* for the self-development of these other powers to which I have referred, even if that self-development has had to be achieved against odds and usually after graduation. The point is that if the objective is to provide educational preparation for *leaders* in the profession, then the development of the powers which characterize such leadership should not be left to chance amid difficulties, but should be purposely fostered.'

This criticism of American educational methods also applies in general to most English-speaking institutions. Indeed similar comments have recently been made by leading British engineers.

Actually the responsibility for these faults is shared by many institutions and individuals; but the major part of it rests with the employers and the Universities. Probably the primary cause is found in the outlook of the general body of employers. It was their insistence on detailed practical knowledge that led the Universities into providing the overloaded curriculums which now prevent students from learning how to think for themselves.

At the same time the Universities must accept a large portion of the blame, for the present position could not have arisen if they had stood true to their original conception of learning as a process for the development of the mind. They should have been the leaders in educational policy, not the mere followers of industrial demands. Therefore they are blameworthy for having allowed their courses to tend towards a vocational rather than a professional emphasis. They have failed also in their responsibilities in so far as they have neglected the importance of corporate student life and general studies as means of developing the personality and social usefulness of their graduates.

In this former connection most English-speaking Universities have much still to learn from their Continental counterparts. There the instruction is designed so that students are compelled to do their own thinking, subject to the general guidance of highly-skilled staffs, and the object of the courses is to develop the student's powers of analysis rather than his capacity for memorizing facts. A few English-speaking Universities have realized the importance of this type of training; and certain British engineers who are in continual and close touch with both types of graduates now affirm that it is the men with the general rather than the specialized education that finally succeed in the profession. Admittedly for the first year or so after graduation these men are overshadowed by their specialist rivals. This initial state of affairs is due chiefly to the fact that the specialists are practically living on their capital, whereas the men with general education are still developing their resources. Once this period is completed and the graduates are faced with new types of problems the men with the general background quickly outdistance their specialist rivals.

Part IV

CONCLUSION

CHAPTER XVI

PROBABLE TRENDS IN ENGINEERING EDUCATION

The Controlling Factors

THE most important of the factors that are now beginning to influence engineering education is that both individual citizens and also the community as a whole are becoming increasingly dependent on the activities and services of engineers and other types of industrial workers. The greater part of the world is now on the verge of a machine-age, and in the near future the whole community will be very vitally concerned with the technical skill and the social viewpoint of the various grades of engineering workers.

A second powerful influence which will affect educational organization is the growth of specialization as the basis of the industrial system. Even now this is having important repercussions on education; and as this principle becomes increasingly well established in industry determined efforts will be made by at least a section of the community to increase its importance in the educational field. Within limits this would be beneficial, as it would lead to a rational system of graded technical education to meet the needs of the chief functional sections of industry. But if the idea should be carried to excess it would destroy the whole value of education by reducing the importance of the general cultural studies. These should form a common, central core to all types of training.

These two tendencies will also have an indirect effect on education since they are gradually changing the type of skill that is required in the trade and vocational sections of industry. Thus the demand for manual skill, as this term is now understood, will be progressively replaced by one for skill in supervising working processes, in understanding the functions of component parts of mechanisms, and in appreciating the importance of utilizing scientific methods in works processes. This changing emphasis will have a considerable effect on the type of education necessary for trade and vocational workers, and will also emphasize the advantages of the school over the works as the location for these types of training. Another point is that the general adoption of mechanical and specialized production will decrease the openings available for unskilled labourers. Thus future educational schemes will have to provide increased facilities for training even the poorest types of students in 'machine-skill.'

Education in any land will also be influenced greatly by changes occurring in the industrial and educational systems of other countries, for as competition for export markets increases each land will endeavour to incorporate into its system of industrial education the methods and organizations which have been of apparent value elsewhere. This tendency should be watched very closely by educationalists for the apparent success of any type of organization in one place is not an infallible indication of its real value in new surroundings. Probably one of the first results of this factor will be the more widespread adoption of a graded system of technical education. To this extent the influence will be a valuable one. But there will also be a temptation to follow the example of certain Continental countries by incorporating technical education into the industrial system instead of retaining it as an integral part of the educational organization. It is most unlikely that this step would advance the ultimate interests of the community.

Another important educational influence is one which is concerned with education for leisure. Ever since the general adoption of machine methods of production there has been a tendency to reduce the hours of work, and a further step in this direction seems probable in the near future. The resulting increase in leisure will have very important reactions on the educational system, as it will necessitate a considerable increase in the general cultural education of most citizens. Otherwise neither the individuals nor the community will really benefit from the reduced working hours. Thus the leisure that arises from increased industrial efficiency will play an important part in controlling the educational schemes of the future. In addition these will be influenced also by that type of 'leisure' known as unemployment. The importance of the educational system as a means of mitigating the effects of this evil have already been outlined, and at this stage it is only necessary to re-emphasize the fact that the future organization of education must be such that the schools will be able to play their full part in improving this position.

In addition to the foregoing factors which will influence the general organization of industrial education, there are others which will primarily affect the professional section of engineering workers. Probably the most important of these is that engineering is now entering upon the intensive stage of its theoretical development. Thus its future leaders will require a much more profound knowledge of the basic sciences than has been necessary hitherto. In the past a knowledge of such broad principles as the Conservation of Energy and the Laws of Motion formed the real basis of an engineering education, but in the future this will have to be supplemented by a thorough acquaintance with laws of the atomic

and possibly sub-atomic realms. Also as the intensive character of engineering work becomes more pronounced the ability to analyze and to reason becomes of ever increasing importance relative to the ability to organize and control workers—an ability which in the past has often been the supreme requirement for engineering success.

Closely allied with this need for a deeper knowledge of the recognized engineering sciences is the fact that future engineers will need to be acquainted with a wider field of sciences than has been necessary in the past. At present physics, chemistry, geology and possibly bacteriology form the scientific basis of engineering practice; but, as the community becomes increasingly affected by and dependent on engineering activities, these professional men will need to be conversant with social and economic subjects which at present are just asserting their claims as sciences. Again research has now ceased to be merely a scientific exercise and is of great importance as an engineering tool. Consequently the education of oncoming professional workers will need a new emphasis. Even now research is of vital importance to many engineering organizations, and as time goes on its influence will be even more widespread. Therefore, although all graduates may not need to be skilled research workers, it is essential that they all should realize the importance and utility of research in engineering activities.

There is still an additional factor which will probably be of very great significance. Reference is made here to the effects which will result from the ultimate establishment of a true professional spirit and outlook amongst this group of workers. Up to the present this factor has been of relatively little importance, for although a professional section has long existed in engineering it has not been adequately distinguished from the associated vocational and trade activities. However, it appears probable that the most highly skilled section of this industry will soon attain a definitely recognized professional status; and as this position is gradually strengthened the profession will take an increasing interest in ensuring that adequate training facilities are available for its future members. Consequently it is probable that the associations of professional engineering workers will play a very important part in influencing the general lines of development of all types of engineering education.

The Probable Developments.—Probably the most important educational change likely to occur in English-speaking countries is the gradual raising of the legal school-leaving age, and the establishment of a more definite, but relatively elastic, link between the periods of compulsory full-time education and of gainful employ-

ment. This will be made possible by the growing use of machinery in industry since this will gradually reduce the necessary duration of the working life. Thus leisure will become a matter of ever-increasing importance in the life of the community. In order to profitably utilize this leisure it will be necessary to raise the general cultural background of society.

Thus it is to be expected that compulsory full-time education will be gradually extended up to an age of sixteen or seventeen years *with the object of ensuring that all citizens obtain a secondary* education and of eliminating that period of casual employment, or unemployment, which under present conditions so often intervenes between the completion of the school work and the start of regular employment.

In this connection it is necessary to realize that the demand for industrial recruits will vary from period to period. Consequently it is desirable that the school leaving regulations should be framed in such an elastic way that the schools will automatically serve as a storage reservoir for those youths who may have passed the normal leaving age without obtaining employment. Also it is most desirable that adequate provision should be made for the continued part-time education of youths who secure employment immediately on reaching the minimum school leaving age.

Also this extended period of schooling will have to be devoted largely to general cultural education rather than to specifically industrial training Actually a development of this nature would be necessary even if the question of leisure did not arise, for as industry advances towards 'complete' mechanization the industrial usefulness of workers will depend to an ever-increasing extent on their general knowledge, adaptability and resourcefulness rather than on skill of a purely technical nature. Consequently it is desirable that the future should not witness any increasing divergence between the early trainings of youths destined for the various functional classifications that exist in the industrial organization.

Indeed what is really needed is a gradual drawing together of the existing educational systems so that in time the terms 'cultural' and 'industrial' will cease to signify differences in secondary education. By the adoption of such an ideal the community would be able to ensure that the great majority of its members possessed a fairly adequate, and commonly shared, background of general knowledge and interest. This should be of considerable value in reducing the sharpness of the class distinctions that tend to be created by specialized education and stratified employment.

Probably it will not be possible to achieve such a programme of

unification for many years, but it is an objective towards which educational authorities should be continually striving. Thus all changes in the educational system should be directed towards closing the gap that now exists between the objectives of the various branches of secondary education, and towards postponing the specialized portions of education until the students have reached a relatively mature age.

An immediate increase of two or more years in the general education of citizens would cause a considerable dislocation of industrial recruiting. Therefore it is desirable that the ultimate objective should be approached by a series of steps. First the minimum school-leaving age should be raised to fifteen years, the additional schooling being devoted to general cultural education. The minimum age for entry into industrial employment should also be fixed at fifteen years; and the conditions of employment in the various trades should be so modified that all recruits would be compelled to attend part-time day classes in technical subjects for at least the first two years of their employment. Provision should be made whereby youths could elect to spend the 15-16 year period in full-time technical education and then enter industry at a status at least equal to that then enjoyed by fellow-students who had gone direct from the general school to industry.

Once the industrial and educational worlds had become reconciled to this first advance it would be possible to begin a second step in which provision would be made for continuing the general education of all students to an age of sixteen years. The minimum age for entry into industry would be correspondingly raised, and the provisions for part and full-time technical instruction would be maintained. Then as a third step the age of industrial recruiting would be raised to seventeen years without any further increase in the duration of the general education so that all industrial recruits would then spend the 16-17 year period in a full-time course of pre-employment training of a predominantly technical nature. Also at this stage any examples of the works' type of apprenticeship which might still exist should be finally abolished.

Thus it would gradually be ensured that practically all citizens received an adequate general education which would provide them with interests outside of their actual employment. At the same time the adoption of the principle of full-time pre-employment training in technical matters would ensure that the necessary industrial skill would be obtained without any undue waste of time. Naturally this does not represent the final goal of educational advance; but it is a reasonable one at which to aim at this present time. Once this goal has been achieved a wide field will open out in connec-

tion with the continued part-time education of workers in general cultural subjects, and also in specialized aspects of their industrial work.

Certain dangers are associated with a highly specialized system of technical training—such as increased risk of mass unemployment and a decreased adaptability of specialist workers. Consequently it is essential that the educational system should go no further than is absolutely essential in this direction. But since industry will always require a large body of trade workers, a smaller body of supervisors, foremen and departmental managers, and a very small proportion of professional workers, it seems desirable that technical education should be specialized sufficiently to meet this basic need. In recognition of this fact most industrial lands have set up graded systems of technical education which provide separate facilities for training each of the three functional groups (namely trade workers, vocational workers and professional workers). Some countries have also adopted logical methods of selecting students for these various grades, and endeavour to maintain a correct numerical ratio between the various types of students; others, however, still leave these important matters to chance. But as international competition increases all nations will be compelled to make the most effective possible use of their labour resources, and so all will have to adopt some logical method of recruiting students for industrial education. Consequently there will be a widespread adoption and development of methods of vocational guidance; and at the same time there will be an intensification of the graded structure of technical education.

Another significant change will be the gradual replacement of part-time instruction by full-time pre-employment training. However, this change will not be fully effective in English-speaking lands for many years to come, and it is consequently desirable to consider the intervening period. In the trade and vocational sections the first step towards this ultimate goal will take the form of a greatly increased activity in the part-time day type of technical instruction. As industry becomes more and more dependent on scientific methods this tendency will be greatly accelerated. Then as employers and workers gradually realize the general superiority of the school over the works as a place for industrial training the earlier portions of this part-time instruction will be replaced by a year of full-time pre-employment schooling, chiefly in technical and manual subjects, while the concluding portion of the training will still be continued on a part-time basis after the recruits have obtained employment.

Concurrent with this gradual change-over there will be an alteration in the nature of the work done in the trade and vocational schools—for manual skill will gradually diminish in importance as

far as the general body of workers is concerned. In its place these men will require an ever-increasing knowledge of mechanisms and of the elementary scientific facts that are utilized in industrial processes. Also since the schools will be used to an increasing extent to reduce the severity of industrial changes it will be essential for the training to be kept fairly broad with the aim of producing adaptable workers rather than specialists.

In the professional level of engineering education the future will be determined chiefly by two factors. The first is that since the functions of the engineering leader and the general practitioner are so distinct dual standards should be established in the undergraduate courses, so that recruits for each group may be effectively educated. Thus it is probable that Honour courses in engineering will be generally adopted in addition to the existing ones of Pass standard. The second important factor arises from the combined effects of the growth of specialized engineering knowledge on the one hand, and of general scientific, economic and cultural knowledge on the other hand. As a result of this dual growth it is certain that an increasing proportion of engineering education will be organized on the basis of non-specialized undergraduate courses associated with specialized post-graduate activities.

As a result of these major changes there will be certain other developments that will merit individual consideration. Thus a natural result of the adoption of Honour courses will be the replacement of distinct and rigidly specified courses of study in each technical branch of engineering by a system which will allow each student to make a personal selection of subjects from a generally approved list of scientific, technical, economic and cultural subjects. Admittedly such a scheme would have to be restricted initially to the Honour students; but as the Universities obtained more experience in administering this type of engineering education it should be possible to extend this method to Pass students.

Another point which will distinguish future courses from the majority of present-day ones is that they will lay a greatly increased stress on developing the personality, initiative and resourcefulness of their students—consequently an appreciable proportion of the total course will be kept free from supervised work, and an added emphasis will be laid on the independent study activities of students.

It will also be increasingly realized that the primary object of the science side of an engineering education is to develop a scientific outlook which will enable students to investigate and analyze situations and problems that are new to them. Consequently students will be encouraged to study sciences which are of special interest to them personally; and care will be taken to ensure that

all engineering students are compelled during the later parts of their undergraduate training to apply these scientific methods of analysis to the solution of typical engineering problems.

Another point which will be of gradually increasing importance is the place that economics and the social sciences will occupy in the undergraduate work. At present if these subjects are included at all they occupy a very minor position; but their importance will increase considerably in the near future. These subjects will finally be included in the undergraduate section of the work since they are common to all branches of engineering. Thus they should form part of the common core which will finally constitute the greater part of all undergraduate courses.

The importance of post-graduate study and research will increase immensely in the near future, since there will be little opportunity for any form of specialized education in the future undergraduate courses. Thus a considerable proportion of graduates will have to supplement their basic work by relatively specialized post-graduate study; while a smaller but not inconsiderable number of men will need training in the methods of research. In the case of general engineering practitioners these post-graduate activities will probably be conducted on a part-time basis, as these men will be interested primarily in obtaining advanced training in some subject or subjects directly applicable to their employment. But on the other hand it is most desirable that the post-graduate work of men who wish to become engineering leaders should be organized on a full-time basis, and that it should be directed towards developing their powers of thought and of critical analysis rather than towards training them in specialized details. Also it is probable that these post-graduate activities of the Universities will be very considerably aided and extended by a growing co-operation between these bodies and the Institutions of Engineers. As these latter bodies achieve a recognized status in the community they will naturally take active steps to promote the higher education of their oncoming members.

In research it is exceedingly difficult to forecast the future; but if engineering is to make its full contribution to society it is essential that its teaching institutions should endeavour to promote research along at least three lines. The first of these arises from the fact that although the everyday processes and problems of electrical, chemical and metallurgical engineering are already fairly closely and clearly related to the basic theories of the corresponding sciences this is true to a lesser extent in the civil, mechanical and mining branches of the profession. Consequently the Universities must endeavour to promote research work to bridge the gaps between the theory and the practice of these branches of engineering. This is vastly more important than the further investigation

of fields that are already fairly well developed, for until these basic relationships are well established it will be impossible for the Universities to develop really satisfactory scientific treatments of these branches of engineering. No University should feel content until all of its technical instruction rests upon this solid foundation.

Research is also urgently required into the relations between engineering practice and the laws of the economic and social sciences. A little work has already been carried out in this field by Continental institutions; but as yet the general problems have hardly been touched. Probably progress in this field of research will be slow, for as yet the basic principles of the underlying sciences are not fully understood. However, the field is one of great importance since the social repercussions associated with engineering activities will be of ever-increasing magnitude.

The third field of research is essentially an educational one, and necessitates the closest possible co-operation between engineers and educationalists. It deals with the problem of developing some adequate system of judging the professional and technical aptitudes of youths who wish to enter upon a career in the professional section of engineering. At the moment the lack of any such aptitude test is one of the major factors contributing to the large percentage of failures in engineering. Consequently the investigation of this general problem is one of great importance and considerable urgency.

As time goes on the semi-vocational outlook which now characterizes many of the activities of the technical faculties of the Universities should be replaced by a truly professional one. If this objective is to be achieved the engineering departments must abandon the old tradition of endeavouring to produce men who will be of considerable value as junior engineers immediately upon graduation. This outlook will have to be replaced by a determination to so develop the mental outlook and the critical reasoning powers of students that, when these take their places in the industrial world, they will be capable of thinking for themselves and of developing their own approach to and solution of technical and social problems. Thus the Universities must realize that their function is to develop the minds of future citizens along fairly broad lines rather than to train men as well-informed technicians. Further they must at all times act in such a way that it will be obvious to the community as a whole that the Universities are the leaders of industrial education and not merely the servants of the industrial system.

Thus the future engineering student should be able to expect that his University education will afford him considerable opportunites for developing his personality and increasing his range of general interest along other than purely technical lines; that it

will bring clearly before him the social responsibilities of his professional activities, and the nature of his duty to the community as a whole; and that it will provide him with an adequate historical background of the inter-relations of engineering progress and social problems. He should also be able to anticipate that the *disciplines* of the basic subjects will clarify his thinking processes, and train him in the logical and critical analysis of complicated situations.. He should be justified in assuming that the experience which he will obtain in applying scientific principles to typical engineering problems will not only teach him how to discriminate between the important and the less important elements of a situation, but also will convince him of the fundamental importance of science as the basis of engineering work. It should lead him to appreciate the importance of simplifying assumptions both as factors which assist in the solution of problems and also as ones which limit the range of applicability of generalized results. In addition his studies should include experimental work to develop his powers of observation and his skill at interpreting experimental results, so inspiring him to search for new truths which will increase the usefulness of his profession as a branch of the social organization.

In addition the student of the future will expect to be given certain knowledge of current industrial practices and procedures. However, this work must be kept subordinate to the other activities, for the ultimate value of a University training is not measured by the volume of technical data which its students accumulate, but by whether or not the minds of these youths are so developed that they are capable of accurate and independent thought in fields that may be fresh to them.

A great deal can be done towards achieving those ends by carefully modifying the form and content of the undergraduate and post-graduate work of the Universities. Nevertheless it is important to remember that the chief factors in attaining such an end are firstly the selection of high class students, and secondly the existence amongst individual members of the University staffs of a definite professional spirit and a will for public service. If staff members regard engineering primarily as a series of technical projects then the majority of their students will go forth with an essentially technical outlook on life. But if the teaching staff definitely shows that it regards engineering as a vital and component part of the life of the community then an increasing proportion of graduates will enter into their life work with a well developed spirit of inquiry and with the object of playing their part in the community not only as engineering experts but also as citizens.

Appendix I

Electrical Honour Course at Yale

Science Stem	Social and Economic Stem		Suggested Electives and Other Information
MATHEMATICS; CHEMISTRY; DRAWING	ENGLISH; NON-TECHNICAL ELECTIVE	FRESHMAN	Electives: History or a foreign language. Students who anticipate graduate work should elect German or French. Introduction to Engineering, E 10, a course of seven lectures and six optional meetings, is usually taken in the Freshman year. Military or Naval Science may be taken as an additional subject. Plane Surveying, CE 10s, is taken at Yale Engineering Camp in the late summer preceding the Sophomore year.
MATHEMATICS; PHYSICS; MECHANICS	ECONOMICS	SOPHOMORE	Normally there are no electives in the Sophomore year. Where it is desired to continue a foreign language begun in the Freshman year, this may be done in special cases by postponing Economics to the Junior year. Military or Naval Science may be taken as an additional subject. Mechanical Technology, ME 10s, is taken in the late summer preceding the Junior year.
ELECTRICAL AND GENERAL ENGINEERING; THERMODYNAMICS	ENGLISH; NON-TECHNICAL ELECTIVE	JUNIOR	Electives: Students with a C average or better may elect (and are advised to do so) either EE 35* or AE 35.** Other suggested electives are: Sociology 10, Sociology 11, Philosophy 37, Industrial Physiology 65, Government 11, Military or Naval Science, and Industrial Management. Electrical Engineering Laboratory, EE 39s, is taken in the late summer preceding the Senior year. *"Projects" course described in the paper. **Human Relations in Industry.
ELECTRICAL AND GENERAL ENGINEERING; STRENGTH OF MATERIALS; METALS AND ALLOYS	SEMINAR; NON-TECHNICAL ELECTIVE	SENIOR	Electives: Students with a C average or better in the Junior year are advised to elect EE 45.* Other suggested electives are the same as those for the Junior year, excepting that if Sociology 10 is taken in the Junior year, Sociology 20 may be elected in the Senior year. Seminar, EE 41: The presentation, both written and oral, of studies relating to the social and economic aspects of technology, and to the history of science and engineering. *Same as EE 35.

←15 Hours Per Week→
(30 credit hours per year)

Appendix II

The following figures are reproduced from the S.P.E.E. "Report on Investigation of Engineering Education":—

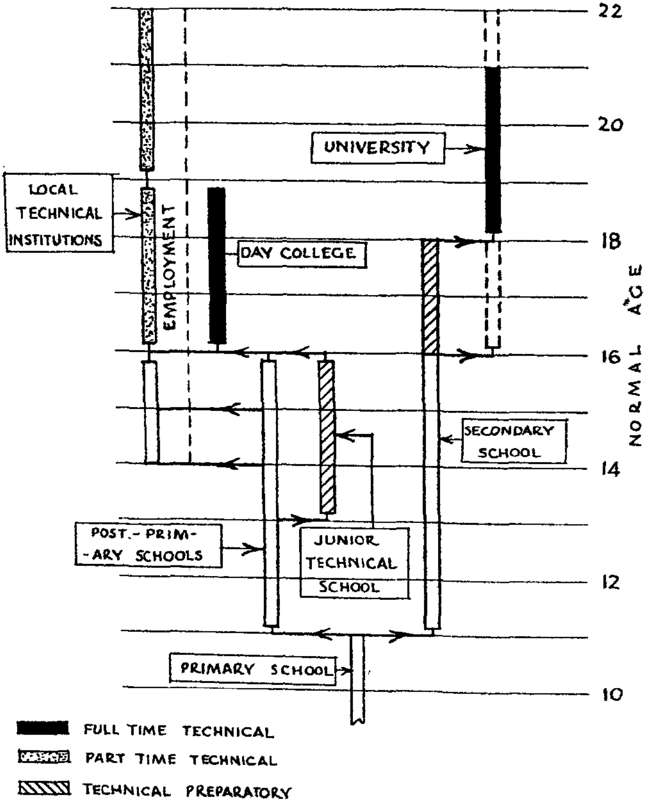

Fig. 1.—Provision for Technical Education in the English System.

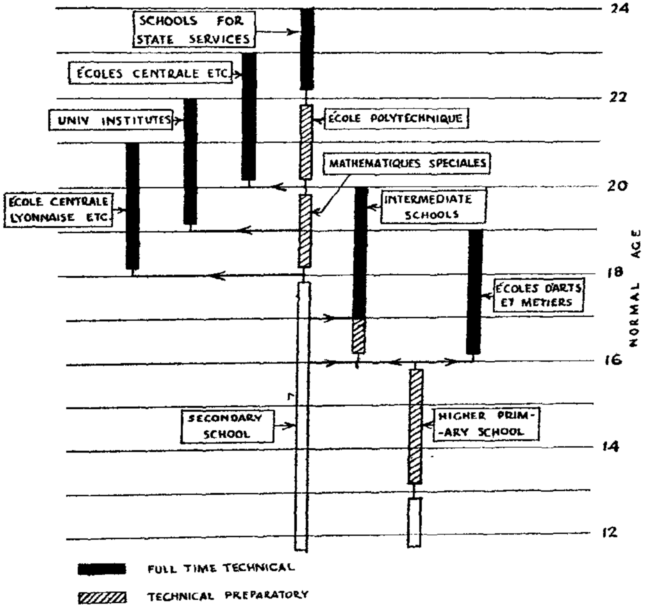

Fig. 2.—Technical Schools of France in the Systems of National Education.

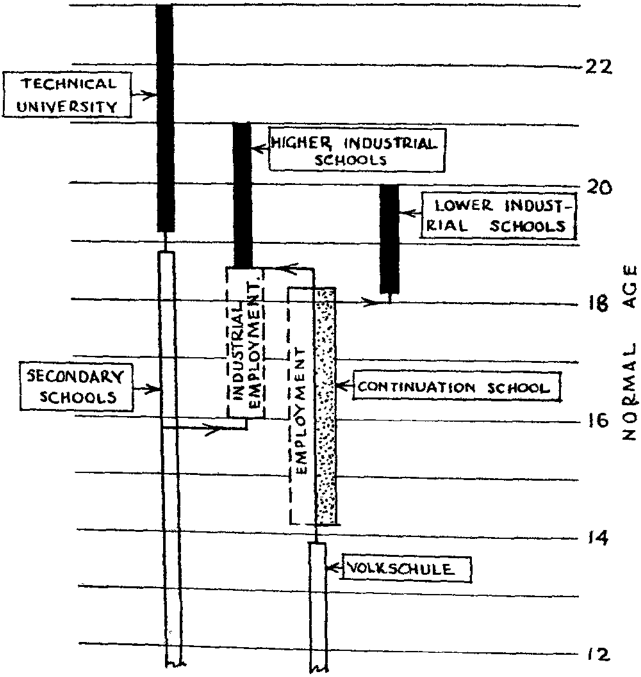

Fig. 3.—Technical Schools in the German Educational System.

Appendix III

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SUGGESTED HONOUR COURSE FOR ELECTRICAL AND MECHANICAL ENGINEERS

TABLE OF SUBJECTS

First Year:

Physics.
Pure Mathematics.
Mixed Mathematics.
Engineering Drawing.
Together with a Science Subject other than Physics.
Vacation Experience (between 1st and 2nd years):
Four weeks in general machine shop work (in a non-University establishment).

Second Year:

Advanced Physics.
Advanced Mathematics.
Engineering Materials and Design.
Engineering Mathematics.
Together with one of the following subjects:
Surveying.
Additional Physics.
Non-technical elective.
Vacation Experience (between 2nd and 3rd years):
Two weeks in either the electrical or the mechanical laboratories of the University, according to line of specialized studies.

Third Year:

Advanced Engineering Materials.
Electrical Engineering.
Mechanical Engineering.
Together with one of the following subjects:
Economics.
Sociology.
Psychology.
Political Institutions.
General History.
Vacation Experience (between 3rd and 4th years):
Four weeks in employ of an approved electrical or mechanical engineer.
Two weeks in electrical or the mechanical laboratories of the University.

Fourth Year:

Advanced Engineering Mathematics.
{ Advanced Electrical Engineering
or
Advanced Mechanical Engineering. }
Engineering Discussion Class.
Together with an additional subject selected from the Third Year Elective Group.

DETAILS OF SUBJECTS

First Year Subjects

Physics (3 lectures and 3 hours practical work weekly).—Kinematics, Statics, Dynamics, Gravitation, Hydromechanics, Properties of Materials, Heat, Wave Motion and Sound, Light, Electrostatics, Electric Current, Electrodynamics, Electromagnetic Induction, Electrical Applications, Electricity and Matter.

Pure Mathematics (2 lectures and 1 hour practice class weekly).—Introduction to Differential and Integral Calculus; Analytical Geometry (straight line and introduction to conics).

Mixed Mathematics (2 lectures and 1 hour practice class weekly).—Kinematics, Dynamics, Statics, Hydrostatics.

Note.—In each of the above subjects work would be carried to a typical First Year standard. For fuller details see information under Natural Philosophy Part I, Pure Mathematics Part I, and Mixed Mathematics Part I in Calendar of University of Melbourne.

Engineering Drawing (3 lectures and 4 hours drawing weekly).—Technique of Drawing; Drawing Conventions; Construction of Cycloids, Involute and Helix; Usual methods of representing three dimensional solids by drawings; Problems in Projection of Plane and Solid Figures; Interpenetration and Development of Surfaces; Sketching of Simple Engineering Mechanisms; Drawing of Simple Bending Movement, Thrust and Shear Diagrams; Graphical Analysis of Loads in Simple Structures.

Second Year Subjects

Advanced Physics (2 lectures and 3 hours practical work weekly).—Properties of Matter; Heat; Electricity and Magnetism.

Advanced Mathematics (2 lectures and 1 hour practice class weekly).—Integration; Differential Equations of First Order, and Linear Differential Equations of Higher Order with Constant Coefficients; Determinants; Infinite Series; Complex Numbers; Plane Geometry (including Properties of Conics); Solid Geometry.

Note.—In each of the above subjects work would be carried to a typical Second Year standard. For fuller details see information under Natural Philosophy Part II, and Pure Mathematics Part II in Calendar of University of Melbourne.

Engineering Materials and Design:

Materials (2 lectures and a 2 hour laboratory demonstration weekly, during first half of the year):

Concrete (component materials, mixing, setting, characteristic properties, sphere of use).

Timber (its structure and influence of this on the uses of this material).

Metals (outline of engineering metals; chief defects; solidification of metals and alloys; microstructure; manufacture; cold working; mechanical properties).

Design (2 lectures and 4 hours drawing weekly during second half of year):

Principles underlying the design of simple joints (including welding).

Fasteners and transmission mechanisms.

Simple framed structures.

Preparation of working drawings.

Engineering Mathematics:

Statics (2 lectures and 3 hours laboratory work weekly for first half of year).—Stress distribution in beams, shafts, columns, pressure vessels, and springs; deflection of beams; collapse of struts; stresses on inclined internal planes; principal stresses; theories of failure in engineering materials.

Dynamics (3 lectures weekly for second half of year).—Theory of machines and mechanisms; dynamics of reciprocating engines; governing of engines; measurement of horse power.

Surveying (2 lectures and 3 hours field work weekly).—Principles and constructions of instruments; chain surveying; levelling; measurement of angles; traversing; reduction of traverses; adjustment of discrepancies; determination of areas; earthworks; curves.

Additional Physics (1 lecture and 2 hours practical work).—Mechanics, Light, Sound.

Non-Technical Elective.—To be a University subject of at least First Year standard.

Third Year Subjects

Advanced Engineering Materials (3 lectures weekly).—

Structure and Mechanical Properties of Cast Irons and Carbon Steels; Case Hardening of Steels; Influence of Nickel, Chromium and Tungsten on Properties of Steel; Defects in Engineering Metals.

Influence of Heat Treatment and of Cold Working on Mechanical Properties of Metals and Alloys; Mechanical Properties of Alloys.

Electrical Engineering (3 lectures and 3 hours practical work weekly; students majoring in electrical engineering will have spent two weeks in electrical laboratory during previous summer vacation).—Units; Instruments; General Circuit Equation; Direct Current Sources; Magnetic Circuit Theory; Characteristics of D.C. Motors; Generation of Alternating E.M.F.; Wave Shape; Transformer Theory; Three Phase Circuits and Calculations.

Papers.—Students majoring in electrical engineering would also prepare papers on certain electrical topics.

Mechanical Engineering (3 lectures and 3 hours practical work weekly; students majoring in mechanical engineering will have spent two weeks in mechanical laboratory during previous summer vacation).—Thermodynamic Theory; Theory of Reciprocating Steam Engines; Indicator Diagram Calculations; Behaviour of Steam in Cylinder; Theory of Steam Turbine; Steam Plant and Accessories; Combustion of Fuels; Boiler Tests.

Theory of Internal Combustion Engines; Typical Engines; Fuels for I.C. Engines.

Theory of Refrigeration; Refrigeration Equipment.

Papers.—Students majoring in mechanical engineering would also prepare papers on certain mechanical topics.

Fourth Year Subjects

Advanced Engineering Mathematics.—This subject would follow the lines of the work included in the book *Mathematics for Modern Engineering* by Doherty and Keller. The subject would have to be taught by an engineer with mathematical ability, and not by a mathematician who had not had an engineering training.

Advanced Electrical Engineering—Advanced Mechanical Engineering.—The details of the work in these subjects would not be

rigidly specified, but would be determined for each individual student. As far as possible the student would be allowed to suggest the general outlines. Students in these subjects would be expected to work individually—the staff concerned co-operating as tutors rather than lecturers. The courses would be kept predominantly theoretical in outlook.

Engineering Discussion Class.—During the Fourth Year each student would prepare papers on appropriate engineering problems. These would be presented to the discussion class in the form of addresses by the students concerned, and would form the subject matter for a round-table discussion in which senior staff members would participate.

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